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# OUR GIANT MOTHS

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ELEGANT in form and beautiful in color, few living things are more attractive than the giant moths. While very few of them are ever harmful to us many are very useful, for from their cocoons come the so-called "wild-silks" of eastern and southern Asia and the East Indies.

Of the moths yielding the "wild silks" the most important are the Chinese and the Indian tussur moths, the moonga and the mezankoorie moths of Assam, and the Yama-mai moth of Japan, all of which are allied to our polyphemus (Fig. 7); the eria or arrindi moth of Bengal and Assam and the cynthia of China (Fig. 6), allied to our promethea (Figures 11, 12) and cecropia (Fig. 1); and the great atlas moth of southeastern Asia with the greatest

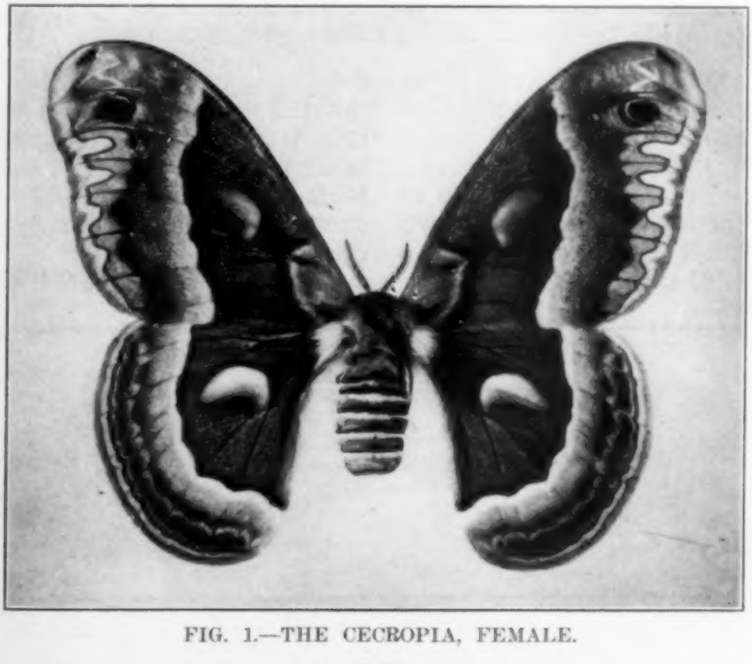

FIG. 1.—THE CECROPIA, FEMALE.

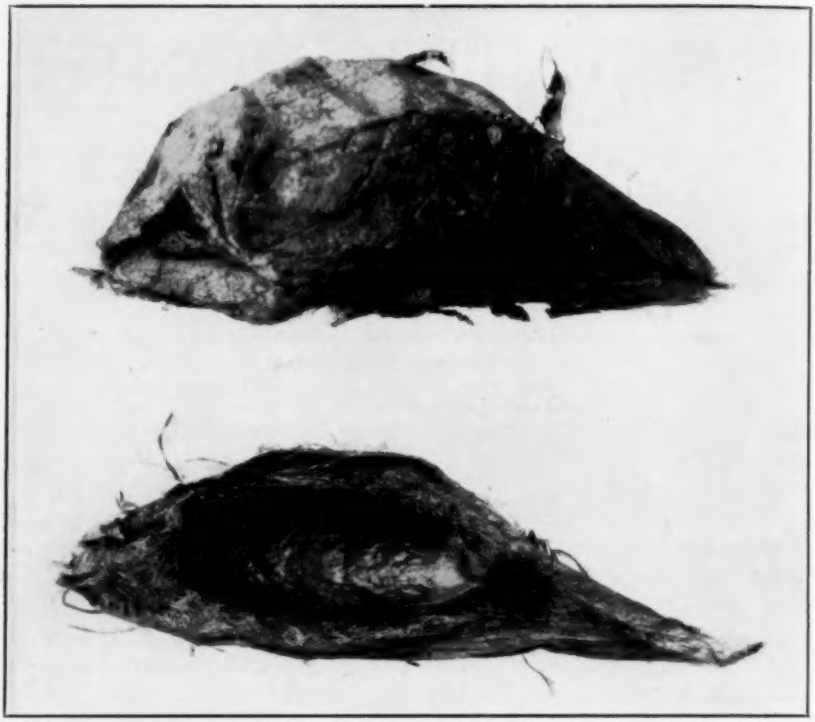

FIG. 2.—COCOON OF THE CECROPIA.
FIG. 3.—COCOON OF THE CECROPIA, CUT IN HALF.

spread of wing of any moth, up to eleven and three quarters inches. Several other kinds are also of more or less importance.

Some of these great moths in the countries where they live are more or less domesticated, and extensive efforts have been made further to develop them as a source of silk in Asia, in Europe and in North America. But in spite of this the so-called silk-worm moth, the only truly domesticated insect, which belongs to quite a different group, still holds first place as the world's silk producer, as it did more than forty-five hundred years ago.

We are so fortunate as to have quite a

FIG. 4.—A VERY SMALL CECROPIA COCOON, FROM WHICH A PERFECT ADULT EMERGED.
FIG. 5.—A CECROPIA COCOON TORN OPEN BY A WOODPECKER.

fair number of these giant moths. From late spring up to mid-summer, occasionally also in the autumn, you sometimes come across them. You notice them most frequently flying about electric lights or perhaps seated on the light pole or on an adjacent tree or fence. Sometimes they flutter at your windows, or you see the males at dusk flying swiftly by with a strong erratic dodging flight or the females flying by in almost a straight line with little deviation. Two of ours fly by day.

often meet with them. But you often find their remains upon the sidewalk near electric lights, or come upon them while walking in the woods.

All our largest native moths belong to a single group known as the saturnians. There are very many moths belonging to this group, most of them found only in the tropics. All of them are large, and some are very large, almost a foot across the wings. The largest live in southern and southeastern Asia and thence southward to Australia.

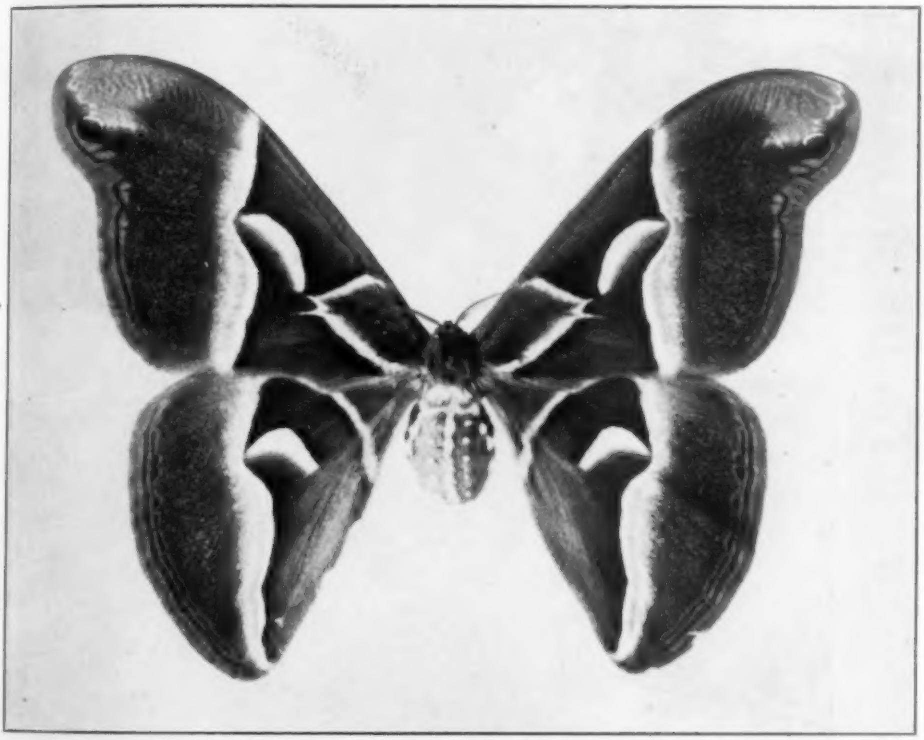

FIG. 6. THE CYNTHIA, FEMALE.

Most of these great moths are really very much more common than they seem to be. Nearly all of them fly only after dark, and mostly high above the ground. Though they sometimes come to lights, as a rule they do not pay much attention to them. In the daytime they remain quietly sitting in the trees, usually high among the branches, so that you do not

A very interesting thing about the moths belonging to this group is that they feed only as caterpillars. In the moths themselves the mouth parts are much reduced, and sometimes almost completely absent. After emerging from the chrysalis these moths can not eat at all, but must live entirely on the surplus food material stored up within their bodies.

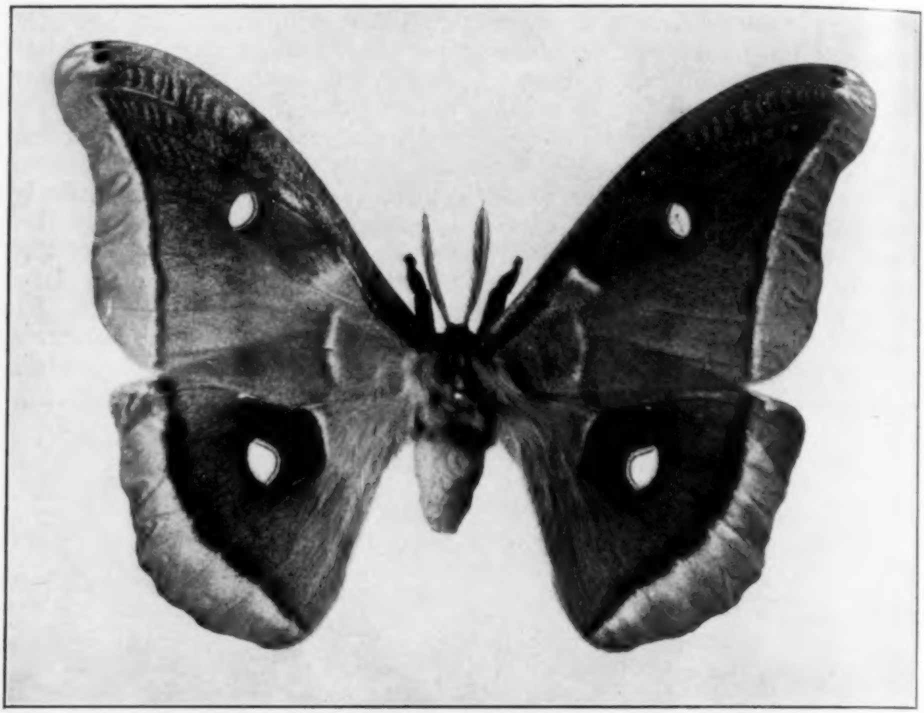

FIG. 7. THE POLYPHEMUS, MALE.

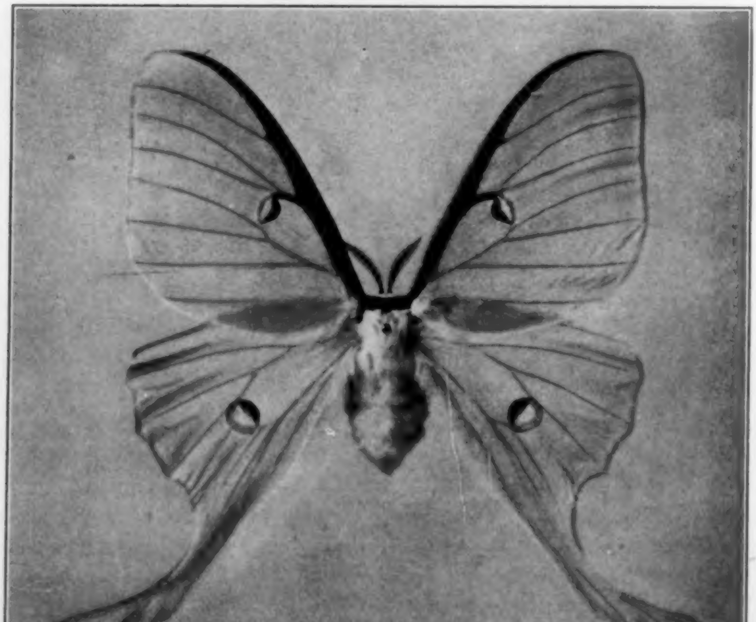

FIG. 8.—THE LUNA, FEMALE.

In the late summer you occasionally find enormous caterpillars, light green in color and very stout, which lack the conspicuous tail seen in the tomato and tobacco worms. These are the young of our giant moths.

With us all these great moths spend the winter in the pupa stage. Most of them construct a silk cocoon which is lying on the sidewalks when the leaves are falling. The caterpillars of a few of these large moths burrow in the ground and form the pupa there.

The largest of our native moths, and a very common one, is the cecropia (*Samia cecropia*). This moth (Fig. 1), which measures up to seven and one half inches across its extended wings, is of a

FIG. 9.—A COCOON OF THE POLYPHEMUS, WITH AN ATTACHMENT TO THE BRANCH; ON THE RIGHT THE COCOON IS SHOWN CUT IN HALVES.
FIG. 10.—COCOONS OF THE LUNA.

tough and thick enough to protect them from the elements. Some fasten their cocoons securely to the twigs of trees so that the wind can not tear them loose, while others spin their cocoons in such a way that they are attached only to the leaves and with them fall to the ground in autumn. You sometimes see these generally grayish color more or less shaded with red. The margin of the wings is earthy gray. Their outer third is marked by a narrow line of white outwardly bordered with a broader line of red. Each wing bears in the center a large crescentic spot of white and red outlined in black. The body is bright

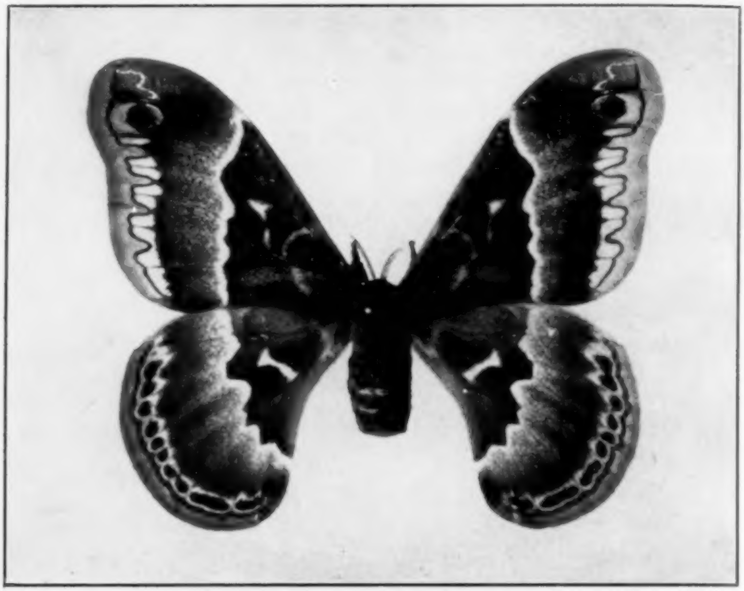

FIG. 11.—THE PROMETHEA, FEMALE.

FIG. 12.—THE PROMETHEA, MALE.

red with a white collar and white stripes across the abdomen. The feelers or antennæ are beautifully feathery, very much broader in the males than in the females.

This moth flies from late in May to the middle of July, and is often seen about electric lights. The large green caterpillar feeds on many kinds of trees and shrubs. The cocoon (Figures 2–4) is attached firmly to a twig along its longest side. It varies very much in size. I have raised a perfect, though small, moth from a cocoon which was only an inch and three quarters long; on the other hand the cocoons may be more than four inches long and much inflated. These large cocoons are usually constructed near the ground. The silk when fresh is reddish, sometimes fairly dark and sometimes nearly white; it fades to dull gray in winter. When constructing the cocoon the caterpillar draws down to it several leaves by which it is concealed. These fall away in winter so that then the cocoons become conspicuous.

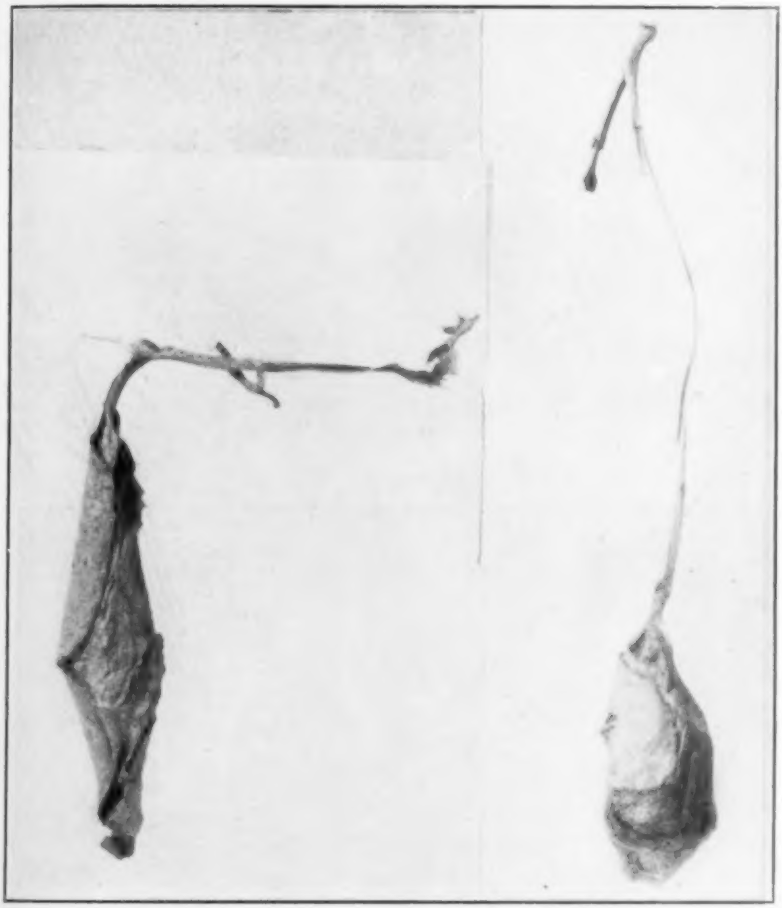

FIG. 13.—COCOONS OF THE PROMETHEA.

The woodpeckers in the winter destroy great numbers of them, tearing a hole in them and through this hole eating out the inside of the pupa (Fig. 5). Squirrels also eat them.

FIG. 14.—THE ANGULIFERA, MALE.

FIG. 15.—THE ANGULIFERA, FEMALE.

In the vicinity of Washington, Philadelphia, New York and Boston there lives a handsome moth known as the cynthia (***Philosamia cynthia***). This moth (**Fig. 6**) is much like the cecropia in its markings, but it is olive green in color, fading to dull yellow, and its wings are narrower. In Washington it is common in late May and June, and again in the first week of August; there is a third brood in October; but at this time the moth is much less common than in the spring and summer broods. Of 250 cocoons taken from a tree in Washington last October, 50 had recently hatched and some of the moths were still about. This would indicate that of this brood about one fifth of the moths hatch in the autumn while four fifths sleep till spring. Many, indeed, sleep on until the middle of the summer when the children of their brothers and sisters are on the wing. The eggs laid by the moths that fly in autumn are all killed by the winter's cold.

This moth often flies by day in the brightest sunlight, when you are likely to mistake it for a great greenish yellow butterfly.

The caterpillar feeds almost exclusively on *Ailanthus* trees. The cocoon is small for such a large moth, and is constructed within a leaflet of the food plant which is wrapped about it; from the cocoon a heavy band of silk runs up the stem of the leaflet and along the midrib of the compound leaf to the twig to which it is attached. Often two or more leaflets are involved in the formation of one cocoon. Sometimes several cocoons will have a common stem, or two or even three cocoons may be spun together in a mass in such a way that the escape of only one of the moths is possible.

FIG. 16.—COCOONS OF THE ANGULIFERA.

This moth was introduced from China as a silk-worm moth in 1861.

Commoner than the cecropia and nearly as large, though much more variable in size, is the polyphemus (*Telea polyphemus*). In color the polyphemus (Fig. 7) is usually tawny yellow with a large black and blue spot in the middle of each hind wing. There is a transparent spot on the fore wing and another in the outer part of the black and blue spot on the hind wing. Sometimes the wings are reddish, and they may vary all the way from cream color to olive or blackish brown; but dull yellowish is the usual shade.

In the north this moth appears only from late in May to the middle of July, but in the south there is another brood in the late summer. About Washington it is seen commonly in late May and June, but only seldom in the autumn.

The caterpillar, which is a bright translucent green with a brown head, is short and chunky. It feeds on very many kinds of trees. Fifty-six days after hatching from the egg one of these caterpillars had increased to four thousand one hundred and forty times its original weight; during this time it had consumed eighty-six thousand times its original weight in food.

The cocoon (Fig. 9) is ovoid, very tough and dense, and is spun usually between two leaves, falling to the ground with them. Rarely the caterpillar runs a thin band of silk up the stems of one or both of the leaves and thus fastens the cocoon more or less securely to the branch.

The most beautiful of all of our large moths is the lovely light green long-tailed luna (*Tropæa luna*). This is a common moth (Fig. 8) but is less often seen than the cecropia or the polyphemus, as it prefers woods to the more open country and does not fly so early in the evening. It usually first appears long after dark and flies till morning, while the others appear at sundown and fly but little in the darkest hours.

The male luna has a much less erratic flight than the males of the other giant moths. Instead of swooping and darting this way and that, as is their habit, it is fond of dancing up and down for several feet about the outer branches of a tree, something like a ghost-moth.

The luna appears abundantly from May to July, and again in much smaller numbers in late August and September.

The caterpillar is very much like the caterpillar of the polyphemus, but the head is green instead of brown and each division of the body has a fine white line around the sides and back. It feeds on many different kinds of trees. The cocoon (Fig. 10) is like that of the polyphemus, but is very thin and papery. It falls to the ground in the same way.

The commonest of all our larger moths is the promethea (*Callosamia promethea*). This is not so large as those just mentioned. The female (Fig. 11) looks like a small dull reddish cecropia, but the male (Fig. 12) is black with a putty colored border to the wings.

This moth appears in late May or early June, usually later than the cecropia or polyphemus, and flies till August. A few are seen in the late summer. The black male flies only in the daytime, with a very irregular swooping and darting flight. It is commonly mistaken for a large black butterfly. The female flies only at night with a direct and heavy flight.

The caterpillar looks like a small cecropia caterpillar. It feeds especially on wild cherry, tulip tree, sassafras and spice-bush, but also on other trees. The cocoon (Fig. 13) is twice as long as broad and is constructed within a leaf which is wrapped about it. A thick band of silk runs up the leaf stem and is fastened to the twig, and sometimes the twig is in the same way fastened to the branch. After the falling of the leaves these cocoons are very easily seen as they dangle from the branches. They are quite common along roadsides and in the more open woods.

Very much like the promethea but larger and much less common is the angulifera (*Callosamia angulifera*). In this moth the males (Fig. 14) are dark brown instead of black with a prominent white angular spot in the middle of the fore wings. The females (Fig. 15) are much lighter and more yellowish than the females of the promethea, with a large angular white spot in the middle of all the wings.

Whereas in the promethea the males are day fliers and the females fly at

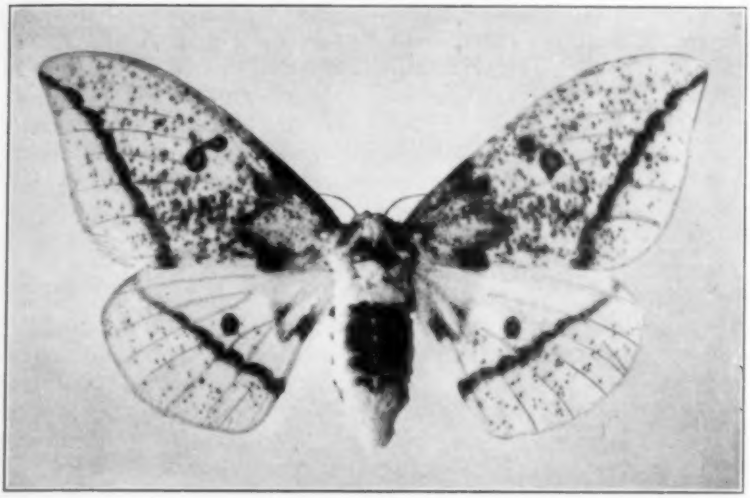

FIG. 17.—THE IMPERIAL MOTH.

night, in the angulifera both sexes are night fliers.

The caterpillar of this moth sometimes makes a cocoon like that of the promethea (Fig. 16), but usually it is not fastened to the twig so that it falls in autumn with the leaves.

In addition to these moths we have three others of a different, though related, group which are remarkable for their large size. Of these the caterpillars do not make cocoons but burrow in the ground and transform to pupæ there.

The largest, as well as the commonest, of these moths is the imperial moth (*Eacles imperialis*) (Fig. 17). This measures about the same as the cecropia across the wings, but the wings are narrower. Its color is bright lemon yellow with dull rose markings which are much more extensive in the males than in the females. It flies only in June. The caterpillar, which varies from green to brown or nearly black and is sometimes spotted, feeds on many kinds of trees, including pines.

Another moth, not quite so large, is the royal walnut moth (*Citheronia regalis*) (Fig. 18). In this the fore wings are grayish olive or purplish with red veins and a few oval yellow spots, and the hind wings are dull orange. It is found in June. The caterpillar is called the "hickory horn devil" and commonly lives on hickory and walnut trees, but also on many other kinds of trees as well.

The pine devil moth (*Citheronia sepulchralis*) is similar in form, but is smaller and dull brown in color. It flies in June and is rather rare. The caterpillar feeds on pines.

Besides these native giant moths there are two others of a very different type spreading about five inches which sometimes stray here. In these the feelers or antennæ are very long and thread-like. Both are abundant in the tropics of America, whence they are sometimes blown far northward.

The commoner of these, called *Erebus odora* (Fig. 19), is brown in color with a more or less marked scalloped line of white across the wings and a dark eye spot near the front border of the fore wings. It lives normally as far north as southern Florida and the warmer portions of the Gulf states, but occasionally is blown far northward, even reaching Canada.

In the tropics it is extremely common. In the hotel in which I stayed in Caracas, Venezuela, these great moths were a perfect pest. They were absolutely everywhere; the folds in the portières especially were full of them. Great numbers of dead ones were swept up from the rooms and corridors each morning.

The other casual visitor from the tropics is *Thysania zenobia,* much like the preceding but light gray with brown markings on the upper side and yellow and black beneath. Normally it just reaches southern Florida and southern Texas, but I once took one in Washington a few days after a hurricane had swept across the Florida peninsula.

Very much like this is the largest of all American moths, the great owl-moth of tropical South America (*Thysania agrippina*) which measures almost a foot across its wings.

This completes our list of giant moths, except for a few which are of more restricted distribution. The two last are only of casual occurrence. Most of the rest are common, and some are very common. You do not often see them, as they mostly stay high up in the trees and only fly by night. But if you know how to go about it you can get them easily.

What is the significance to us of these giant moths? In the first place none of them are sufficiently abundant to cause us serious trouble. The caterpillars of the polyphemus alone have sometimes proven destructive in limited areas; but they are large and easily controlled. The numbers of this moth are usually kept well within bounds by parasites and birds which kill the caterpillars, as well as by rats, squirrels and moles which tear open the cocoons and eat the chrysalids.

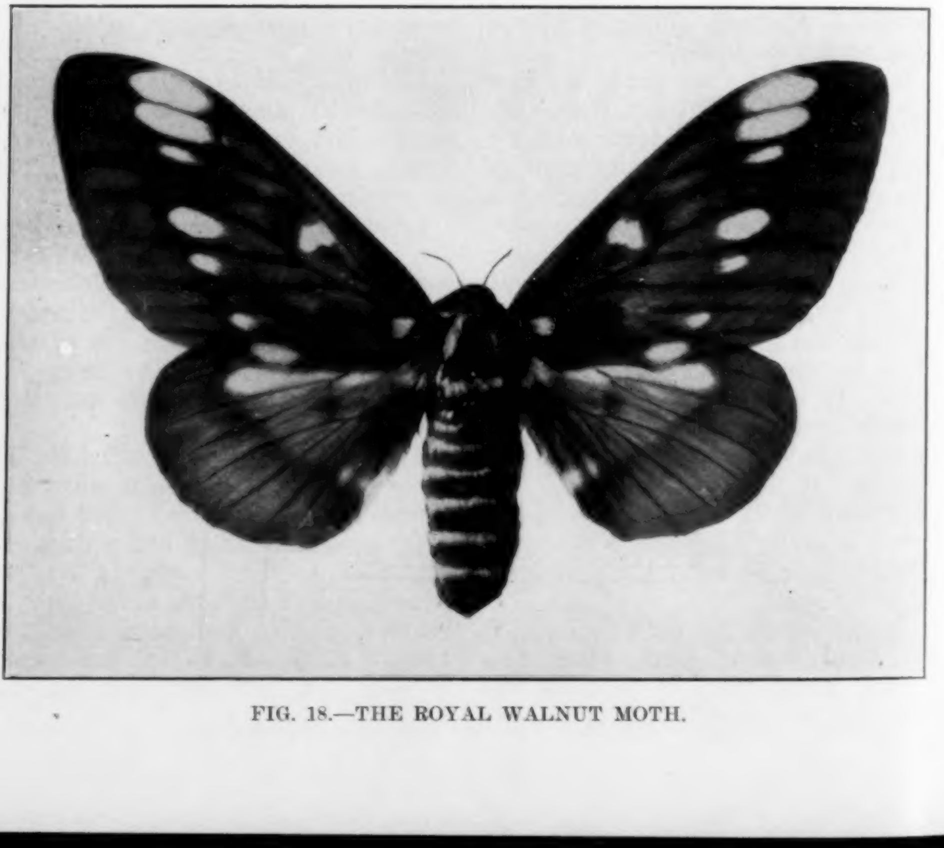

FIG. 18.—THE ROYAL WALNUT MOTH.

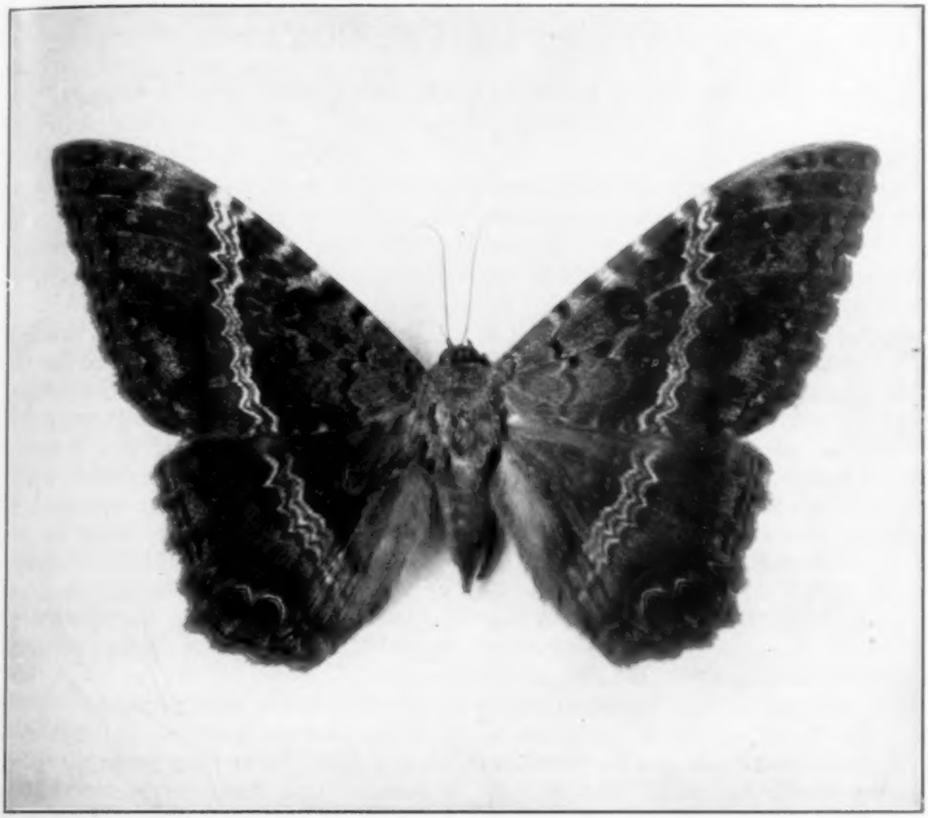

FIG. 19.—*EREBUS ODORA.*

Many efforts have in the past been made to utilize the silk in the cocoons. The cocoons of the promethea (Fig. 13) and the angulifera (Fig. 16) are so very dense and so very strongly gummed that the silk can not be reeled; but the cocoons of the cynthia, which are very much like these, are of a looser texture and are widely used for making silk in China.

The cecropia and its allies make a large cocoon (Figures 3–5); but in spinning it the caterpillar leaves one end open for the exit of the moth which prevents the reeling of a continuous thread, though it is possible to card the silk. Although quite strong the silk has not much brilliancy, and the caterpillars are too delicate to be raised in numbers.

The cocoon of the luna (Fig. 10) is so thin and frail and the silk so weak that it is not possible to reel it.

The silk of the polyphemus has a very strong and glossy fiber and the cocoon is closed at either end (Fig. 9). Sixty years ago great hopes were entertained that this moth might become an important silk producer, like its relatives in eastern Asia. In 1865 on one estate alone not less than a million of these huge caterpillars could be seen feeding in the open air on scrub-oak bushes covered with nets; five acres of woodland were swarming with them.

But this thriving colony was wiped out by a disease brought to this country with the eggs of an allied moth imported through Paris from Japan.

# ATOMS OF ENERGY[1]

By Dr. PAUL R. HEYL

BUREAU OF STANDARDS

ONE of the earliest of the great scientific achievements of the nineteenth century was the establishment of the atomic theory of matter. The idea was not new. It had been suggested by the ancients; Newton and Boyle had used it as a working hypothesis; but the final establishment of the theory came only after the work of Dalton.

Prior to Dalton atomic ideas had been purely qualitative; he was the first to recognize the significant fact that whole numbers played an important part in chemical combinations. This fact, for which no explanation could be given on the hypothesis that matter had a continuous structure, was seen at once to be a simple and natural consequence of the theory that matter was composed of indivisible atoms which by their union with each other gave rise to the whole number ratios expressed by Dalton's laws of simple and of multiple proportions.

The fruitfulness of the atomic theory has been remarkable. The whole of modern chemistry is founded upon it; and while such physical phenomena as can be formulated by the principles of thermodynamics or of relativity may not, perhaps, require the atomic concept, in most physical theory it is supreme.

So long and so completely has the atomic theory dominated scientific thinking that many to-day may find it hard to realize that there could ever have been any other point of view, at least of late years; yet the theory that matter was continuous in structure had its adherents all through the nineteenth century, including men of the standing of T. Sterry Hunt, the geologist, who died in 1892. The last notable opponent of the atomic theory, Ernst Mach, of Vienna, died as recently as 1916.[2]

It is interesting to notice that this last adherent of a lost cause lived to see the atomic idea, after conquering the domain of matter, invade that of energy; for it was in 1900 that Planck[3] put forward the hypothesis that energy, which up to that time had been tacitly accepted as continuous in its nature, must be regarded as made up of indivisible atoms, or quanta. So fertile has this concept proved that it may be permissible to style Planck the Dalton of the twentieth century.

But just as the atomic concept was not entirely new to Dalton, so the idea that energy might be at least irregular in its structure had been suggested before Planck. J. J. Thomson, in his Princeton Lectures on the "Discharge of Energy through Gases" (1898, page 42), mentions with some wonder that by subjecting a gas to the action of X-rays the number of charged ions produced in the gas was very much smaller than might reasonably be expected. With hydrogen, for instance, less than a million millionth of the gas was ionized. Even with vapors of iodine and of mercury, much better conductors than hydrogen, the fraction of the gas ionized was still negligibly small. Thomson's explanation of this fact, later given, was that the wave front of the X-rays was not uniform, but rather of a beady or lumpy structure, the energy being concentrated in spots and spread out thin elsewhere.

[1] Published by permission of the Director of the National Bureau of Standards of the U. S. Department of Commerce.

[2] Brauner: *Nature*, June 28, 1924, page 927.

[3] Planck: *Verh. d. deutsch. phys. Gesellschaft*, 1900, page 237.

Only when one of these intense spots of energy happened to strike a gas molecule would an ion be formed, the thinner and weaker portions of the wave front being unable to produce this effect.

Carry this idea to its logical limit; concentrate all the energy in a number of spots of great intensity, with interspaces completely devoid of energy, and we have the modern conception of a light wave on the quantum theory. Such a wave front, if sufficiently magnified, would present not a uniform field of illumination, but a number of intensely bright spots rather sparsely scattered on a dark background.

Thomson's suggestion is interesting as a forerunner of later ideas, but like the atomic theory before Dalton it lacked the quantitative element. This was supplied by Planck; and as with the atomic theory, it was the quantitative touch which gave the new concept its fertility.

In putting forward the suggestion of the atomicity of energy Planck had not in mind the phenomenon described by Thomson, but was led to his hypothesis by a certain long-standing difficulty in the theory of radiation. Many attempts had been made to find a formula which should represent the distribution of energy in the spectrum of a glowing body, but without complete success. Agreement with experiment was in no case satisfactory in the region of the longer wave lengths, though fairly acceptable in all the rest of the spectrum. The accuracy of the experimental results did not escape suspicion; but careful and repeated work confirmed the discrepancy. Planck finally concluded that agreement would never be satisfactory on the basis of the existing ideas of the nature of energy. The new idea which he put forth is suggestive of Dalton in that he pointed out the importance of the part played by whole numbers.

According to classical ideas a vibrating molecule or atom might contain any amount of energy and lose it gradually by radiation, the retained energy diminishing in amount by imperceptible stages. Planck denied this, and asserted that the contained energy must always be a multiple of a certain fundamental unit called the quantum. This unit is so small (of the order of a million millionth of an erg) that it may be said that there is no perceptible difference between this and a continuous structure; yet the same might be said of atoms of matter. As a matter of fact, the sizes of both atoms and quanta are sufficient to make a noticeable difference.

According to the idea proposed by Planck, when a molecule gains or loses energy it must do so by sudden jumps, one or more quanta at a time, and not by a continuous change. The difference between this concept and the older idea may be illustrated by a box containing a number of equal marbles. If the contents of the box vary, it must be by jumps of one or more marbles; and the weight of the marbles in the box at any instant must always be a whole multiple of that of a single marble. But if the marbles be finely pulverized the whole numbers disappear, and continuous change is possible.

Revolutionary as was this concept it has abundantly justified itself and has doubtless come to stay. Applied to the previously unsatisfactory radiation formula it produced the change necessary to remove the discrepancy with experiment in the region of the long wave lengths without spoiling the agreement in the rest of the spectrum. This alone would have been a sufficient justification, but it was not all. Planck had builded better than he knew.

A similar discrepancy had long existed in the theory of atomic heats. Every student of chemistry learns Dulong and Petit's law, which states that the product of the specific heat of an element by its atomic weight is a constant quantity. Stated in this tradi-

tional form it is but a poorly obeyed law, for the "constant" turns out to have unexpected and unaccountable fluctuations, especially at low temperatures. Here we have again a law that fails at one end. It was but natural that the quantum concept, which succeeded so well in the similar case of the energy of the spectrum, should be called into play in this connection also.

The first to make this application was Einstein, whose contributions to the quantum theory have been so important that had he never written a word about relativity his reputation would still be second only to that of Planck. Einstein was followed by others (Nernst and Lindemann, Debye, Born and Karman) who added successive improvements to Einstein's formula until the erratic behavior of the atomic heat was satisfactorily expressed. Still again, in connection with the curious phenomenon known as the photo-electric effect, the new concept showed its power. Here the action of light upon certain metals causes them to emit electrons. Einstein applied the quantum concept, and succeeded in obtaining by its aid a satisfactory formulation of the phenomenon. But by far the most important and far reaching of all the applications of the quantum idea has been that by Bohr to the structure of the atom. This, however, is too long and perhaps too familiar a story to be told here.

In its successful application to these cases that we have mentioned the quantum concept finds its justification for existence; it works well where the classical theory breaks down.

It must not be inferred from this that the classical theory has suffered a complete rout, and that the quantum concept is an undisputed conqueror. Far from it. In certain matters, especially in the domain of interference, it is the classical theory that works well and the quantum concept that is helpless. The present situation as between the two theories is a deadlock. As Lodge says, the two concepts are like a shark and a tiger, each supreme in its own element, and helpless in that of the other. The solution of the difficulty lies undoubtedly in attaining some broader concept of which the two will be seen to be special cases.

As yet we have no satisfactory mental picture of a quantum. There is much to suggest the old idea of light corpuscles, but just as forcibly as a hundred years ago the phenomenon of interference puts an end to that. There must be something periodic in the structure of a quantum.

This conclusion is strengthened by the fact that different quanta have not all the same energy value. Their magnitude, measured in units of energy, varies with the source which gives rise to them. For example, the energy in a beam of red light appears to be made up of units each of the value of $3 \times 10^{-12}$ erg, while the units of violet light have double this amount of energy. The energy of a quantum is proportional to the frequency of the vibration of the source which emits it.

Attempts to visualize a quantum have not been lacking. One of the earliest suggestions was that it might be a train of waves of finite length, a "dart," as Silberstein called it. And since interference can be obtained with a difference of path of the interfering rays of fifty centimeters or more, it follows that a quantum would have to be that long; for interference can take place only between two trains of light that have started from the same source at the same time.

But Lorentz[4] called attention to the fact that a similar line of reasoning would indicate that a quantum must be several times as broad as it is long. In Michelson's work on star diameters interference was obtained from rays that were as much as six meters apart. The simile of the dart is, on such considera-

[4] Lorentz: *Nature*, April 26, 1924.

tions, replaced by that of a piece of corrugated iron roofing.

Moreover, a quantum of energy must be capable of entering the pupil of the eye, or of being absorbed by the much smaller electron, an operation suggesting the celebrated packing of the genie into a bottle.

It is evident from the contradictions arising from these different considerations that we are dealing with something much broader and more general than any of our present attempts to grasp it. In this respect we are like the three blind men of the Hindu story who went out to see the elephant. An obliging friend led them to the place where the elephant was, and said: "Now, there he is, just a few steps in front of you. Go and examine him." And they advanced slowly with outstretched hands.

The first man happened to touch the trunk of the elephant. He felt it up and down, and said: "How wonderful! An elephant is like a young tree with rough bark!" But the second, who felt the elephant's tail, said: "How can you say that! An elephant is much like a piece of rope!" And the third, who touched the side of the creature, said: "You are both wrong; an elephant is like a great, broad, flat wall!"

A notable attempt to form a mental picture of the quantum which shall be free from absurd contradictions has been recently made by J. J. Thomson.[5] He suggests that the quantum may be a ring or closed Faraday tube of force travelling through the ether unchanged in size or shape, surrounded by a system of Maxwellian waves, their wave length being equal to the circumference of the ring. This gives the quantum its periodic element, though Thomson does not regard these waves as instrumental in producing interference, nearly or quite all of the energy of the quantum being in the ring. The function of the waves is to guide the ring in its path as it travels.

Thomson considers the statistical average distribution of these quanta (which is all that the eye or photographic plate can detect) and comes to the conclusion that after passing a slit they will be spread out in such a fashion as to simulate the well-known appearance of interference bands.

The strength of this suggestion of Thomson's lies in its breadth and inclusive character. He recognizes that the undulatory and the quantum concepts both have a valid reason for existence, and attempts to combine them into a dual structure, one part of which is similar to that of the undulatory theory and the other to that required by the quantum concept. Both parts of the structure, ring and waves, have lines of electric force as a common foundation.

The effort spent in attempting to reach a satisfactory mental picture of the quantum is evidence of the recognition of the fact that the concept is here to stay, and that we must do our best at an understanding of it.

The inadequacy of the classical wave theory to account for such phenomena as have become familiar to us of late years is perhaps not widely appreciated. One of the best cases of this kind is found in the photo-electric effect. The argument is well summarized by Jeans in his "Report on the Quantum Theory."

There are certain metals such as sodium which emit electrons when light of a certain critical frequency or higher falls upon them. For sodium, this critical frequency is in the yellowish green of the spectrum, with a frequency of $5.15 \times 10^{14}$ vibrations per second. Light of a frequency equal to or greater than this will cause an immediate emission of electrons, while light of any lower frequency, no matter how intense or long continued, will have no such effect.

[5] Thomson: "Fison Memorial Lecture," 1925. Cambridge University Press.

This immediate emission of electrons can be explained on the wave theory only by some sort of resonance or trigger effect. If there is in the sodium an electron vibrating with this critical frequency, and with such energy that it is just about ready to break loose, it might be that a very slight stimulus from the light wave would bring about the liberation of the electron. On this hypothesis we are to suppose that there are in the sodium electrons vibrating with all frequencies from the critical frequency upward, but none of lower frequencies. It appears impossible to reconcile such an idea with spectroscopic evidence. Every solid when heated to incandescence gives a continuous spectrum containing all frequencies, high and low; and even the more limited spectrum of gaseous sodium contains lines of lower frequency than the critical photo-electric value.

But without some such trigger effect the absorption of sufficient energy to liberate an electron would require more time than is actually the case. Campbell states this point excellently in his "Modern Electrical Theory" (1912):

> A photo-electric effect can certainly be observed when the energy falling per second on one square centimeter of the substance is much less than one erg, . . . and the energy of each electron liberated by it can certainly be greater than $10^{-12}$ erg. . . . On the ordinary theory of light an electron can not absorb more energy than falls upon the molecule in which it is contained; but the area covered by the cross section of a single molecule is certainly less than $10^{-15}$ square centimeter. It appears then that no electron could acquire the energy with which it actually emerges unless the light had acted for one thousand seconds, or about a quarter of an hour. . . . As a matter of fact, the effect appears to start simultaneously with the action of the light.

As a desperate attempt to retain the wave theory in such a case as this it has even been proposed to abandon or modify the doctrine of the conservation of energy. The difficulty is that there is not enough energy in the wave front at any point and at any time to do the required work, and yet the work somehow gets done. It has been suggested that when a continuous wave front strikes an electron the latter is stimulated so that in some way it actually creates in itself a quantum of energy, while to balance this there is an annihilation of energy over some other part of the wave front, not necessarily adjacent, and not necessarily happening at the same instant of time, so that statistically and on the large scale the balance is maintained. However, such experimental tests of this as are possible seem to negative the supposition.[6]

Recently what has been called the New Quantum Theory has been put forth by a group of physicists headed by Born, of Göttingen. We must not over-understand the adjective "new" in this connection. The theory is simply a new system of mathematical formulation, and not a new mental picture. It has often been remarked that in their predilection for mental pictures and models the British physicists stand apart from their Continental brethren, who appear to be satisfied with a set of abstract mathematical formulas.

The student of the quantum theory as it stands to-day must not expect too much. The theory is but a lusty infant, though growing rapidly. Enough has perhaps been said to justify the statement that the quantum theory embodies the most important concept yet brought forth by the twentieth century. The theory of relativity, its only competitor, is already showing signs of reaching a barren stage, while the quantum concept, though some years the older, is still fertile and vigorous.

[6] C. D. Ellis: "The Light Quantum Theory," *Nature*, June 26, 1926.

# PATHOLOGICAL PHYSIOLOGY

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HUMAN physiology is a Janus-faced science. One of its faces is turned toward the wide sciences of biology: those making the *form* of living matter their study, as anatomy and its microscopic subdivision, histology and those investigating the function of organisms: comparative and general physiology. If we consider the enormous range of life, the varied forms which it assumes, passing in review at land and sea, in amoeba or mammal, the pure importance of human life, stripped of its associations, will dwindle. And still, emotional interest in the human body is such that human physiology outgrew all its due proportions and is now towering above the more general biological sciences. Here modern science goes arm in arm with Scripture and religion: all plants and animals of the world are made subservient to man's egocentric interest and even the "purest" scientist can not help but harken to the constantly recurring bearings of his particular science upon human physiology. Beyond biology, physiology leans back still farther upon the exact sciences: physics and chemistry and physical chemistry. And in the distance looms the quantitative thought, the mathematical thought. All physical science strives for a quantitative basis, all physical science is eager to create laws: It is ultimately *nomotopic*. And to reach this aim, two processes are necessary: (1) analysis, to simplify events and break them up into their components; (2) synthesis, upon the basis of broad induction which concludes in quantitative laws.

But physiology shows another face, too. It is turned toward the clinic, toward pathology. As Claude Bernard says: "La science ne consiste pas en des faits, mais dans les conséquences qu'on en tire." It is a general human tendency—supported by modern utilitarianism—to be pragmatic, and thus Bernard's consequences are apt to obtain a narrower meaning than intended by that great physiologist. The methods and results of physiology have been gradually translated into clinical terms and form the large foundations of modern internal medicine. All that is science in medicine is physiology because it is through her that the strict nomotopic demands of the exact sciences are felt and are complied with.

At one end of the scale, then, stands normal physiology. Its aim is the elucidation of the functions of the normal organism, both qualitatively and quantitatively. On the other end stands internal medicine, based and built, both on its diagnostic and therapeutic side, upon physiology—but evidently upon a changed and enlarged physiology. This physiology has for its aim the establishment of laws under which organs and organisms work *when diseased*. Of course, disease as a deviation from normalcy has often a scarcely discernible borderline. At one end the normal function may be retained, at the other, obliterated both in time and space. It is obvious, therefore, that normal physiology is at the bottom of explanation of all disease, but equally obvious that it is enlarged in scope. It has to consider deviations and their mechanism and in this widened scope fits in the new science of pathological physiology.

As to method, patho-physiology employs the method of the sister-science which is the experiment. On account of this method, patho-physiology quite often, particularly in Germany, sails under the name of experimental pathology. But experimental pathology may be primarily interested not so much in pathological changes of *function*, but in those of *form*, and then we have the experimental branch of morbid anatomy. There is such a thing as experimental morphology and we should isolate sciences regarding rather their scope than their method if that method is common to so many of them. I think that the influence of that famous statistician, Karl Pearson, is quite responsible for the persistence of methodological classification.

Let us consider the chief problems of this attractive science. In the field of the heart and circulation the ground is open in cardiodynamics. Normal physiology endeavors to establish the laws which govern the output of blood, the speed of the flow of blood through arteries and veins, and tries to set our whole knowledge of the circulation upon firm foundations of mathematical mechanics. This phase of physiology is becoming fast one of the most exact fields of physiology. The facts which it investigates are easily reducible to simple events, and methods of physics have been successfully applied. A step further is taken, when deviations from the normal function are produced. The methods producing these deviations are usually accessory to patho-physiology and might form part of another science in their scope. To illustrate: The valves of the heart very often show leakage, they do not regulate the movement of the blood from one chamber to another with accuracy but permit blood to regurgitate in the reverse direction. Such conditions can be experimentally produced by injuring the valves mechanically. Now, patho-physiology is concerned with the mechanism which results from such a leakage and it hopes that after the laws governing that mechanism are established, we will have a clear understanding of what goes on in the living human being under similar conditions. *How* the original anatomical lesion causing the leakage occurs is an entirely different question and would fall at present within the scope of experimental morphology whose aim it is to study the diseased *form*. I say *at present*, because all anatomical interest might be exhausted after a while and physiological problems—such as the behavior of diseased cells in the valves under the influence of infection, etc.—might come to the fore. Another great field for patho-physiology of the heart is the elucidation of various abnormalities within the heart-muscle itself—without reference to its dynamic aspect—the point of attack of the elegant method of electrocardiography. Or take the recent development in the study of the capillaries. Until recently the capillaries were neglected, neglected in spite of the fact that they form the bulk of cross-section of the total blood-containing equipment of the organism and that it is through them directly that the all-important exchange of oxygen occurs. Professor Krogh, of Copenhagen, pointed out the intricate mechanism and the widespread independence of these minute tubes and this important work opened up research into the changes of this mechanism in disease. Every phase of normal physiology has its immediate counterpart in patho-physiology, and not one but several counterparts, because there is but one normal condition, but the deviations from it are manyfold.

Very closely interwoven with the main function of the circulation, *i.e.*, the oxygenation of the tissues, are two other vital systems, that of respiration and the structure of the blood. The

study of respiration approximates the quantitative ideal of science: the intake and distribution of air (according to depth of inspiration) has been measured; similarly, the concentration of oxygen and carbon dioxide in the innermost recesses of the lungs. We know many details of the mechanism of the oxygenation of the blood, the limits of the saturation with oxygen, the factors influencing this saturation. Normal physiology teaches that the total quantity of hemoglobin (the oxygen-carrying pigment), the speed of the blood flow through the tissues, the (partial) oxygen pressure in the lungs are some of these factors. Each one of them may be expressed mathematically. Patho-physiology endeavors to alter these factors one by one and is at length able to find a mathematical formula for the pathologically insufficient saturation of blood with oxygen, a complicated condition, which the clinician expresses with the simple word "cyanosis."

The microscopic structure of the blood has been claimed as a separate field of medical science, so-called hematology. This field has been ploughed with great industry, particularly by Germans—so well adapted to painstaking detail work—but, from the point of view of *form* alone. A great field of pathological anatomy of the blood has been evolved with endless classification and nomenclature. The pathological physiology of the blood—which is a complex and important *organ* and not a mere passive "rolling stock"—is just beginning to rise. One of its interesting problems is the influence of the endocrine system upon the production of blood cells. It is very likely that organs like the suprarenal glands, the thyroid gland, etc., have a definite effect upon the creation of certain types of blood cells. A deviation in these relationships and there might develop the immensely complex group of "blood-diseases," diseases rather of the blood-forming apparatus (such as the marrow of the bones, lymph-glands, etc.).

The influence of these same glands upon our ability to resist infection is similarly a new channel. The suspicion is widespread among physiologists that most of the "anti-bodies," which are our main weapons against invading germs, are produced by the lining of the omnipresent capillaries. On the other hand, it is well known that these very capillaries can easily be influenced by hormones. Very promising combinations may thus be thought of which show that patho-physiology links together such widely divergent territories as endocrinology and hematology.

This brings us in contact with the study of infectious diseases. It is the province of pathological physiology to investigate the conditions—chemical and mechanical—under which a microorganism might attack the living tissue. It is further its province to investigate the migrations of these organisms and the production of poisons. Of course, much of this is open to anatomical methods, but there are many infectious diseases in which the localization and development of the specific poisoning can be determined solely by the experimental methods of physiology. Classical example in this respect is tetanus (lockjaw). The way the toxin of the tetanus-bacillus creeps up along the stem of nerves, the way it settles in certain portions of the spinal cord and the way the affected nerve cells change their reactions are all facts open to physiological experiment, but hidden to anatomic research. The complex phenomena of, *e.g.*, typhoid fever or the relatively simple ones of pneumonia—the latter deeply affecting certain chemical processes of the body—fall one by one under the domain of pathological physiology. The relationships between the "reaction" of the

body and the evolution of infections is another field inviting attention.

Metabolism is one of the most rewarding sections of pathological physiology. The discovery of insulin showing the intrinsic relationships of endocrine glands to metabolism brought this home to the public. But this discovery does not bring us nearer to the solution of the diabetes problem; science still fails to evaluate all the conditions governing the utilization of carbohydrates. Disentangling one fact from another in the erstwhile so chaotic chemical processes, pointing out the substances which are the turning point in the transition of one great group of food substances to another is the task undertaken by physiological chemistry, which in turn serves pathological chemistry. These are after all but branches of normal, respectively pathological physiology. The discovery of the "accessory" food substances was guided primarily by clinical considerations: by the recognition of "deficiency diseases." The physiology of an organism deprived of certain of its vitamins is pathological physiology, and this pathological physiology carries in and with it diagnosis and treatment of the resulting diseases. Pathological physiology is not only physiology. It *is* medicine.

Physiology has recently begun to utilize in an ever-growing degree the achievements of physical chemistry. This science covers the territory adjacent to both physics and chemistry. Many of its problems have been investigated in the human body and its very exact methods taken advantage of. Such problems are, taken at random: the permeability of the cells for various substances, the study of acidity and alkalinity of the organism and the intricate questions of colloid chemistry. All these problems have found their modifications in the light of pathology, and all the exact methods of physico-chemical physiology are now in the service of pathological physiology. This means that among many other things our understanding of one of the most vexed problems in medicine, that of Bright's disease, will be more complete. Anatomical research, which assumed the leadership in pathology for the past half century, although having admirable work to its credit, has to take the blame for the burdensome confusion now reigning in this particular field. Physico-chemical processes, however, are at the bottom of cell-life and so we really can not restrict the field of physico-chemical pathology to just one organ or one system. Its scope is immense and research just touched upon its possibilities. That research will slowly concentrate upon the functions of the diseased cells, giving a modern and exact rendering of Virchow's famous phrase, "Zellular-pathologie."

It would be easy to survey all organs and glance at the various workshops of pathological physiology; no organ is inaccessible any more, the operations of each one of them are being watched with keen interest both in health and in disease. This science offers the best opportunities for observation, the best methods of attack; and while it concentrates upon its chief aim, to wit, to establish *laws of disease* and put pathological happenings in the body upon a quantitative foundation, applying the experimental method, it also keeps its eyes open for data that nature offers in her ordinary pace. It would be an important and timely thing to round out and define the field of pathological physiology, fit her into a scheme of medical education, create a chair for her and start her on intensive and concentrated work. In one word, she deserves a place in the sun.

# THE FILTERABLE VIRUSES AND THEIR NATURE

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In the early days of modern bacteriology the discovery of a causative relationship between a number of bacteria and certain infectious diseases gave rise to the hope that ere long all infectious diseases of hitherto unknown origin would be linked up with organisms of this order. But notwithstanding most painstaking investigations in this direction, this hope was not fulfilled. This seemed rather remarkable. Smallpox, for example, was evidently not due to the activity of any one of the many bacteria which had from time to time been isolated from the pustules on the skin and the various internal organs. Such organisms were concomitant of the disease and responsible for some of its complications, but they could be ruled out as the causative agents of the malady proper. The fact, however, that association on the part of a single individual with a smallpox patient could give rise to a widespread epidemic of the disease was evidently an indication that the causative agent underwent rapid and extensive multiplication, and multiplication naturally suggested the activity of living matter. As bacteria were then viewed as the lowest forms of life, it seemed to follow that a bacterium must be the cause of such a disease as smallpox. Similar considerations seemed to apply to many other diseases affecting both man and animals, such as hydrophobia, infantile paralysis, mumps, trachoma, measles, the hoof and mouth disease of cattle, hog cholera and many more. As bacteria such as they were known until very recently could be seen with the microscope, but as no bacteria that had any causative connection with the corresponding maladies could be discovered in the affected organs, the question naturally arose whether low forms of *animal* life, visible only with the microscope, might be responsible. A number of infectious diseases, like malaria and amoebic dysentery, had as a matter of fact been traced to protozoa, as the lowest known forms of animal life are termed. There yet remained a large number of very evidently infectious diseases, however, in which neither by attempt at cultivation or by means of the microscope evidence of the presence of foreign living matter could be detected.

In view of this situation two possibilities suggested themselves as affording an explanation of the origin of such diseases. On the one hand, it was conceivable that living organisms might exist which were too small to be seen with even the very excellent instruments which were available at the end of the last century. On the other hand, there arose the question whether mere infectivity on the part of a disease necessarily implied the activity of an animate agent.

The idea that ultramicroscopic organisms might exist was suggested already by Pasteur, when he failed to find bacteria in the brain and spinal cord of animals which had succumbed to hydrophobia, while the inoculation of minute quantities of such material into other animals produced the malady in question. Subsequently the belief in the existence of apparently invisible organisms and their causative relation to infectious diseases of unknown origin gained many

adherents, but it was not until 1892 that a disease-producing agent of this order was actually discovered. In that year a Russian scientist, Iwanowski, demonstrated that an infectious disease affecting tobacco could be transmitted to healthy plants by inoculation of small quantities not only of the freshly expressed juice obtained from sick plants, but even after filtration through stone filters of great density. In 1896 Iwanowski's observations were confirmed by the Dutch scientist, Beijerinck, and at the same time greatly amplified. Inasmuch as the infective principle of the disease was capable not only of passing through dense porcelain filters with which Beijerinck worked, but permeated thick layers of a dense agar jelly, this investigator drew the inference that the agent in question could not be an organized body. As the inoculation of the minutest trace of the infective material into healthy plants produced the disease, and as this could be transmitted, moreover, through long series of plants with the resulting infection of the entire body of the plants, he concluded that the mysterious agent in question must be endowed with life, notwithstanding the supposed absence of a corpuscular form. He accordingly developed the concept of a contagium vivum fluidum, *i.e.*, of a non-organized but animate disease-producing body. This concept, it must be mentioned at once, could not be upheld, for it was shown subsequently that the permeation of the infective principle was after all the permeation not of a substance in solution, but of a corpuscular body of such minute size that its constituent particles were capable of entering even such minute pores as exist in agar jelly.

In the same year in which Beijerinck published his findings, and apparently in ignorance of the latter's work, Löffler and Frosch made the announcement that the dreaded hoof-and-mouth disease of cattle was found by them to be due to an apparently invisible agent which was capable of passing the pores of the finest stone filters and of infecting in mere traces. Notwithstanding their inability to demonstrate anything visible either directly or in attempted cultures of the filtrate, they concluded that the principle in question must be animate.

The reason for this, as in Beijerinck's work, was the observation that by starting with a minute quantity of the infective material they could serially infect an unlimited number of animals, and that healthy animals, when placed in the same stable with such that had been inoculated with filtrates, nevertheless contracted the disease. In other words there was abundant evidence to show that the infective agent underwent reproduction and that the possibility of serial transmission was not due to progressive dilution.

Löffler and Frosch were fully aware of the significance of their discovery and expressed the view that subsequent research would probably establish that yet other infectious diseases of heretofore unknown origin were caused by ultramicroscopic organisms.

The search for microorganisms of this type was then begun by many investigators and is going on even more actively at the present day. As a consequence a long list of infectious diseases affecting man and many animals, as well as plants, is now known to be caused by filterable viruses, as these agents are collectively called. The term "virus," of course, has reference to the infectious, pestilential nature of the maladies caused by these organisms, and the attribute "filterable" to their extremely minute size, in virtue of which they can pass filters which, generally speaking, hold back all other types of living matter, *i.e.*, bacteria and protozoa. Of the diseases in question which affect man may be mentioned hydrophobia, smallpox, infantile paralysis, measles, mumps and trachoma, which is responsible for

so much misery the world over. Even the innocent fever blisters, of the actual significance of which in relation to those diseases which they accompany, nothing is as yet known, common warts and certain febrile diseases, such as dengue, so-called pappataci fever and possibly chickenpox and the type of sleeping sickness which has appeared of recent years in the wake of influenza epidemics belong to this order. Some investigators, on the basis of an increasing number of successful inoculation experiments in animals with tumor material which had been passed through stone filters, further incline to the view that malignant growths affecting the human being even may be due to agents of this type.

Among the diseases which affect animals an equally large number have been traced to the activity of filterable viruses, many of which are of great economic importance, such as hog cholera, cattle plague (Rinderpest), chicken plague, poultry pox, several infectious maladies affecting sheep and goats, certain diseases of horses, possibly also the distemper of dogs and many more, in addition to the hoof-and-mouth disease in which Löffler and Frosch made their basic discovery. Even among the lower animals filterable viruses play an important rôle. In the case of the silkworm a certain infection of this order leads to disastrous consequences and may cause great economic losses. A closely related virus attacks gipsy moth caterpillars and causes a fatal disease among these, but unfortunately from the standpoint of the agriculturalist it seems to be difficult to bring about sufficiently extensive epidemics of this malady to serve as a serious check to the activities and extension of these insects.

As has been mentioned at the outset the existence of filterable viruses was first discovered in connection with a disease affecting tobacco. This is known to plant pathologists as mosaic disease. While it does not lead to the destruction of the plant it renders the leaves unsuitable for wrapping purposes and detracts from its proper aroma. Similar diseases have been found to affect a large variety of plants, in some of which the activity of a filterable virus has already been definitely established, while in others this is as yet only suspected. When affecting such plants as corn, sugar cane and wheat the malady produces great losses, owing to the effect which the viruses in question have on the growth and development of the plants.

A few years ago certain observations were made which suggest that even the lowest class of plants, *viz.*, the bacteria, may become attacked and succumb to the action of a filterable agent—the so-called bacteriophage—and that this process can be induced serially as in the case of the virus diseases to which animals are subject. Much of this work was initiated and developed by d'Herelle, and an impetus was thus given to investigations which have opened up new fields for study, the importance of which can even now hardly be estimated.

In the earlier days of the study of the filterable viruses the mere fact of their ability to pass stone filters, whose pore size was such as to hold back all the then known bacteria, was regarded as a sufficiently characteristic criterion to serve as a dividing line between the visible and the supposedly invisible animate world. Later researches, however, have demonstrated that bacteria exist, which either owing to their form and power of locomotion, even ordinarily, *i.e.*, at any stage of their lives, are able to pass filter pores which hold back other bacteria, or which at a certain stage of their development assume such a minute size as to enable them to do this. Such filter passing organisms, however, can not be viewed as filterable viruses proper, for all of them can be cultivated on artificial media where they form colonies which can for the most part be seen with the naked eye

and without difficulty with even the lowest powers of the microscope. The filterable viruses proper, on the other hand, can hardly be said to be cultivable on artificial media, and where some semblance of their at most temporary persistence under such conditions has been noted colony formation has never been observed. In the very few instances where actual unlimited propagation has been achieved outside of the body, this has been brought about by the use of artificially grown tissues of the host animal which the viruses in question are normally capable of parasitizing. The filterable viruses, as a matter of fact, appear to be highly specialized parasites which are incapable of existing outside of the animal or vegetable body, and in many instances apparently even outside of certain tissues or even of certain cells.

In some diseases it is possible to make out the presence in the affected cells of enormous numbers of tiniest granules, so tiny in fact that an ordinary bacterium in comparison appears like a perfect giant, and some investigators incline to the belief that these granules represent the corresponding virus particles themselves. In other diseases, however, it is not possible to discern anything showing any form, even with the highest powers of the microscope. Nevertheless, even in these it is possible to demonstrate that the infective principle is corpuscular in character, *i.e.*, that it is not a substance present in solution, but a particle held in suspension, for on filtering material of this order through so-called ultra filters of progressively diminishing pore size, one ultimately reaches a point where the virus is held back, as is evidenced by the absence of infectivity of the filtrate. As it is possible to determine the pore size even of such dense filters as these, it is also possible to determine the size of the infective virus particle. Studies in this direction have led to the discovery that some of the filterable viruses, such as that causing the mosaic disease of tobacco and the virus of chicken plague, must have a diameter of only thirty millimicra, one millimicron representing the millionth part of a millimeter, and one millimeter being equivalent to 0.03937 of an inch.

The discovery that some of the filterable viruses are of such a minute size has naturally raised the question whether they can possibly be animate. If we look upon their evident multiplication in the infected host as evidence of reproduction *ex eo ipso*, *i.e.*, as resulting from the successive division of the virus particles, then we must also assume the existence in such particles of a process of nutrition, both of a constructive and a destructive type, and such an occurrence, so far as our present knowledge goes, would doubtless imply the existence of life. But inasmuch as the diameter of the infective particle is such that the corresponding cubic contents would hardly admit of the presence of even such a comparatively simple nutritional and reproductive mechanism as the smallest of the common bacteria possess, we must assume such viruses to be much more simply organized, and this in turn raises the question whether we would have the right to regard such organisms as bacteria in the ordinary sense of the word, and, if not, what are they.

Hitherto we have been in the habit of looking upon bacteria, such as we can see through the microscope, as the lowest forms of living matter, but in view of the fact that infinitely smaller organisms are now known to exist, the question arises whether it is rational to assume that in the evolution of living matter from non-living matter the chasm between the two was crossed at one leap, or whether it does not seem more likely that it was gradually filled in and crossed by degrees. In other words, the question is whether between the most lowly organized bacteria and the type of non-living matter from which living matter was derived, there may not have

developed a world of living organisms as extensive and as varied perhaps as the world of living matter that we see before us to-day, either with the naked eye or aided with the microscope, but a world of life of whose existence until recently very few had ever dreamed. While the writer is willing to admit that future research may show that some of the organisms which are now classified among the filterable viruses may prove to be bacteria or protozoa in the present concept of these terms, having perhaps been modified in their behavior in consequence of their exclusively parasitic existence through the eons, he is inclined to look upon these smallest forms, which may properly be termed ultraviruses, as representing living matter of such intermediate type, the existence of which we have postulated on theoretical grounds.

As we have reason to believe that the number of species of bacteria which are pathogenic for higher forms of life only represent a small fraction of the entire bacterial world, it would seem logical to assume that in a world of still more primitive living matter, also, only a certain number would be endowed with disease-producing properties in reference to higher forms of life, and those which were capable of attacking man and the domesticated animals, more particularly, would naturally be the ones which in the course of time would first attract the attention of investigators and thus lead to their discovery. To demonstrate the presence of these disease-producing forms in a given instance, and in particular their animate nature, is often a very difficult matter, but to penetrate the realm of the corresponding non-pathogenic, *i.e.*, non-disease producing forms is from the nature of conditions infinitely more so. Only a very occasional investigator has, as a matter of fact, attempted to enter this domain, but has encountered portals which ordinary keys evidently are incapable to unlock. It does not follow, however, that with more suitable methods an entry may not be effected. Whether or not d'Herelle actually had a glimpse into this world when he found that ultrafiltrates from a certain sulphur spring brought about the reduction of mineral sulphates under laboratory conditions remains to be seen. The field is so vast and the workers along these special lines are as yet so few that much time will probably have to elapse before our knowledge will be materially increased.

At the present time it would seem indicated to concentrate our efforts on the study of the filterable viruses proper, *i.e.*, on that group of protobes, as all these forms of ultra primitive life might collectively be termed, the existence of which is recognizable by the diseases to which they give rise.

It has been pointed out above that the animate nature of this group would appear to be indicated by the power of its members to produce disease in series, as this would suggest their reproduction *ex eo ipso*. But the question has been raised of late whether the mere possibility of serial transmission of a disease constitutes actual proof that the causative agent must be living. In this connection certain observations of Baur are of special interest. This investigator found that a disease affecting certain plants, which is known to plant pathologists as infectious chlorosis, can be serially transmitted, but not by the injection of the juice of diseased leaves. But, if a diseased twig is grafted on a susceptible plant and the graft has once "taken," the malady appears in all leaves which are at the time in process of formation or which are subsequently to be formed by the host plant. Any one of the resultant twigs, when placed in suitable soil, will develop into a similarly diseased plant. It is thus clear that the disease-producing principle is being reproduced, but inasmuch as it

does not appear in the juice of the diseased leaf in an infective state, it would seem that it must cause the outbreak of the malady in hitherto healthy parts of the plant in an indirect manner, and certain investigators have accordingly assumed that it can not be animate. Whether this conclusion is warrantable on the basis of the observed facts may perhaps be questioned, but, if the active principle were assumed to be animate, we would be confronted with a manifestation of life which could certainly not be reduced to living matter of any type with which we are acquainted. The recognition of the possibility, however, that a serially transmissible disease need not necessarily be due to an animate agent, has raised the question whether some of the filterable viruses may not be inanimate, and if so, of what nature the principles in question may be. This question has arisen more especially in connection with those viruses which are capable of passing some of the denser ultrafilters, such as the virus of chicken plague and the bacteriophage. In connection with the latter the strife betwixt the supporters of its animate nature and those who regard it as inanimate, has indeed been a very strenuous one, and it would seem that in spite of the enormous amount of work that has already been done, the question was as yet far from being settled. d'Herelle, the discoverer of the bacteriophage, has advanced many weighty arguments in favor of his contention that it is a living organism, and arguments, moreover, which his opponents have often overlooked or at any rate failed to meet. Some of his opponents' claims regarding the nature of the bacteriophage certainly appear just as fanciful, to say the least, as his own.

In connection with the study of certain infectious tumors of fowls which appear to be closely related to, if not identical with certain cancerous growths affecting the higher animals, including man, the same question has been raised. Here also the active agent is a filterable virus which is capable of producing these tumors in series and shows a number of characteristics which we have been in the habit of connecting with living matter. But, as it has been possible to produce these tumors artificially by injecting fowls with minute traces of chemical substances of known composition, together with normal embryonic tissue, with the resultant appearance of a filterable agent which is capable of producing the same type of growth in series, it would seem, on first consideration, that this agent could not be animate. If, however, we were to assume that we have present, widely distributed in nature, a living virus or viruses which, while usually innocuous, could be rendered disease-producing (in this instance tumor-producing), under such conditions or similar ones to those which we have just set forth, we could understand how an animate filterable, tumor-producing agent might appear in the resultant growth, with which the same types of growth could then be reproduced in series. The sequence then would be the development of more or less specifically diseased cells in the host, the invasion of these by an ordinarily innocuous, more or less omnipresent animate virus, and the consequent transformation of such diseased cells into cancer cells. Whether or not this is the process or one of the processes by which cancers actually originate is now under consideration. Many facts could be adduced in support of such a hypothesis.

The question, of course, arises whether we have any evidence that viruses actually exist which may be present in the body without causing disease at one time, while at other times they produce harmful effects. Our knowledge along these lines, it must be admitted, is as yet very meager, but we do know at least of one virus which manifests such a behavior. The virus in question is one which is responsible for the formation of the com-

mon fever blisters and those forms which in the layman's mind are referable to some disorder of digestion. Medically this condition is spoken of as herpes simplex. In certain febrile diseases, such as pneumonia, it is especially common, so common indeed that we could predict its appearance with a fair degree of accuracy in a given case. As its appearance follows the outbreak of the pneumonic process the question arises, where was the virus before? Three possibilities suggest themselves, *viz.*, (1) that the virus entered the body with the pneumococcus (the pneumonia-producing organism), (2) that it entered following the latter's invasion, or (3) that it was previously present in the individual's body in an innocuous form. If the second possibility represents the actual situation we would be forced to assume a nearly ubiquitous occurrence of the virus of herpes and its activation by the pneumonic process. This would virtually amount to the same as the third possibility, as in the absence of the pneumonic process invasion, even if it did occur, would not be followed by an attack of blisters. In connection with the first possibility we should be forced to assume a coexistence of the virus with the pneumococcus, but of this we have as yet no experimental evidence. The fact, however, that herpes develops in so many people in the absence of an infection and frequently periodically, would suggest that the third possibility, suggested in connection with pneumonia, is probably the more likely one.

It would thus appear that the possibility of producing tumors—in the fowl at any rate—by the injection of chemicals and embryonic tissue, does not exclude the cooperation of a virus, and no sound argument has as yet been raised to warrant the assumption that the filterable tumor-producing principle which appears in the resultant growth is not animate. If, as Carrel claims, these chemically produced tumors are identical in nature with the spontaneous tumors which occasionally occur in chickens, and of which the so-called Rous tumor is a typical example, additional evidence of the animate nature of the corresponding virus or viruses would be available, for Rous has shown that the virus discovered by himself is capable of adaptation. When he first encountered a malignant tumor in a chicken, of which a filterable agent was the cause, he found that this particular growth, be it by grafting or the inoculation of filtrates, could only be transmitted to other chickens if these were of the same variety, and at first indeed members of the same family. In the course of time, however, he succeeded in transmitting it to other varieties as well, and at the present time the same strain of virus seems to have lost all the host specificity which it originally possessed; it has gradually adapted itself to chickens in general. The power of adaptation after all implies the ability to exist in an unaccustomed milieu, and when coupled with evidence of reproduction under such conditions implies the existence of life, and considered from this point of view all the filterable viruses, so-called, with which we are at present acquainted, may more appropriately be regarded as animate than as inanimate.

# THE ODYSSEY OF SCIENCE

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In making a modest study of the text of Herodotus, so far as was possible for one who knew little Greek, I attempted two or three years ago to cull from it something for the readers of this journal which might arrest the attention of scientific men.[1] In the course of the work I was led to the desire to attempt to supplement it by reading the Odyssey for the same purpose, but other interests intervened. In selecting from my notes[2] now I find it best to pick up the thread of interest in the Odyssey in the article on the Science of Herodotus.

It is not a matter that warrants farther extension here, but I was somewhat surprised to find the latter had evidently borrowed his information in regard to Libyan lambs being born with horns[3] directly from Homer.[4] We get at once the revelation which is easily to be found in Greek literature that Homer was, after five hundred years, the source of science, religion and history from which men largely drew their inspiration in the zenith of the glory of Greece. Herodotus has dated Homer for us four hundred years before he himself was born, and we see him dipping here into his lines for one of his diversions from the paths of history, which is the way he says he likes to write it. It is a pity more of science and more of history can not be written in the same way. This may have been one of the crumbs Aeschylus says were being constantly picked up from Homer's table, but as there are in Herodotus extended remarks of biological interest on the subject, it may still in his day have been an interesting piece of knowledge to be picked up among the Egyptian savants where Homer himself may have found it.

This, however, was observed afterwards and was not what especially struck the spark that blazed into my desire to read the Odyssey in Greek. In the article in this journal referred to above I displayed some interest in the growing literature of the lost Atlantis. It is very astonishing to note the volume to which in various forms this has grown. Despite the very decided way in which geological science has negatived the assertion of the plausibility there is in Plato's tale—all science in fact has contributed its disapproval of any time spent in the discussion of such a notion —that not long before historic times, geologically speaking, a continent sank below the waters of the Atlantic beyond the Pillars of Hercules and perhaps carried down a civilization with it, still the discussion goes on. Even since the recent date of the note of interest I let drop in the matter, two or three years ago, a great deal of more pretentious and of course more important publication in regard to the old old tale has

[1] SCIENTIFIC MONTHLY, June, 1923.

[2] Besides the Oxford text by Monro and Allen, I have had advantage of the four volumes thus far published of Bérard's work, the text and introduction with its voluminous comments and critical remarks, also of Allen's Homer, Origins and Transmissions. These, published in 1924, are the latest additions to interminable lists of similar works on the Iliad and Odyssey to be had for the asking in the larger libraries, stretching back to Pisistratus, 2,500 years ago. The Unity of Homer, by Professor Scott, 1921, has also been in my hands.

[3] "Herodoti historiarum," libri IX, ed. H. R. Deutsch (Teubner), IV. 29.

[4] "Homeri opera," Monro and Allen, Oxford, Od. IV; 85.

seen the light. Not to more than mention such excellent books as Spence's[5] and Dévigne's,[6] whose authors make no attempt at original scientific analysis, there has on the contrary been published some work very worthy indeed of serious scientific examination. How much weight the argument of Brousseau[7] in a critique of the Wegener-Joly hypothesis of cosmogony has with geologists I do not know, but Schmidt in tracing the birthplace of eels, from two continents at least, to the supposed site of the Atlantis can not fail to arouse the interest of biologists in the theory of an inherited instinct in eels' plasm to seek for their birthplace a situation where perhaps ten or twenty thousand years ago they had riparian rights. Something analogous has been worked out for salmon. The article of Louis Germain,[8] assistant at the National History Museum at Paris, is still more suggestive from a biological standpoint. His citation of the land and marine life of the eastern brink of the Atlantic and its homologies with that elsewhere and with the paleontological evidence may be refuted, perhaps, but it can not be ignored. These authors conclude that the only rational hypothesis which can explain the facts they and others adduce is to assume the existence once of an ancient continent which extended over the rather vaguely placed area of the Sea of Saragossa which the *Arcturus* has been unable to find and as far eastward as the Atlantic islands which lie off the coast of northern Africa.

Far be it from me to presume to enter into any review of the highly technical biological and geological and archeological and ethnical and historical—for the evidence permeates all these domains which enters the endless arguments on the subject. I only take this opportunity of referring to the recrudescence of the discussion. In going over some of it in a desultory way I noted a reference to a passage in the Odyssey which supported the author's rather visionary speculations on the subject, but he did not give chapter or verse and I myself forget the book or article and its author's name whence I got the hint. I set out to find anything in the Odyssey to warrant it in various translations, but missed it. Annoyed, like the Chinaman who burned down his house to roast the pig, I turned and read the whole text through and it has carried me far into a land of delight, while the original trifling excitation to enter it almost passed from view, so I do not know whether this was what the author busy with the question of the Atlantis meant or not. When Nestor in sandy Pylos is in talk with Telemachus in search of news of his father he advises him to seek out Menelaus, who on his way home from Troy, lately returned, had come from a strange country—from the land of men whence none would hope in his heart to return when once the storms have driven the wanderer into so wide a sea. Thence even an eagle or a vulture could not make its way in the space of a year, so great a sea it is and so wide. That is somewhat the way Butcher and Lang translate it, I found after I had lingered long enough over it in the text for me to think what some one had said about the Atlantis. There were one or two expeditions, much more complicated than the one fitted out by the son of Odysseus to hunt his father, which were, as I read, being equipped to try to drag up some scrap of loose ware from that sunken continent, whence it took the birds so long to come in view of old Nestor at sandy Pylos, out past the Pillars or Pyloi of Hercules towards Sandy Hook. The present is linked up

[5] "The Problem of the Atlantis," by Lewis Spence, London, 1924.

[6] "L'Atlantide," by Roger Dévigne, Paris, 1924.

[7] *Revue Scientifique*, 1924, Nos. 15 and 16.

[8] *Revue Scientifique*, 1924, No. 15 and 16.

with the past by a thousand subtle ties and perhaps the old hero had dimly in his mind the story that was old long before Plato wrote or Homer sang.

Jowett thinks very likely Plato invented the story himself to begin with. He was quite capable of it, he thinks. Homer, no doubt, invented a lot of things about Troy and we moderns for centuries believed he invented Troy, but it has not proved so. Nestor he may have invented, but it is likely there were mariners' tales of very many things, of very many lands, and some of those tales we can be sure were lies and that distant shore whence the sea eagles came, if strong enough of wing, recedes for us into impenetrable mist. Still—

Some of those mariners with lies to catch the land-lubbers they traded with were Phoenicians who heired the naval power of Crete when it fell and Knossus was sacked. It may have been the Cretans who brought the news of the sinking of the Atlantis; indeed, the sea power of Crete has been advanced in the argument as to how the tradition arose, but such blatter is such stuff as dreams are made of. Who knows, however? The sea power of Crete may once have been a great factor in the life of the Mediterranean civilization and when the empire fell it was a cataclysm indeed that was heard all around the little world of the Middle Sea. That might have been the mighty power that sank into oblivion. That very likely was news, some suppose, the Phoenician merchant pirates told in the old sea ports and thus the story became a continent which sank beneath the waves. That is the only news, so far as we know, the Phoenicians could have been old enough to carry. It may have indeed been a very garbled story in the mouth of one so wise, but so old as Nestor. As the Odyssey flows along we never think it is not Nestor speaking, but Homer, so realistic and impersonal is he. Homer too doubtless gathered his inspiration not alone from the breath of the sea and the surge of its waves, but from the mariners who sailed it and dropped into every port to liquor up.

While ethnologists, turned historians, as so many scientists tend to become nowadays, may be interested in the ethnic origin of the Phoenicians and may be compelled to turn over the pages of history to get some insight into that mystery, the interest of all scientists is attracted by the advent in history of the invention of letters or rather their evolution to portable and cursive script. There is another matter, parallel in a way, in the history of the knowledge of iron which recedes also into obscurity. The practical use of both bids fair now to be dated more or less definitely and with both we find the activities of the Phoenicians intimately connected, evidently not as inventors or discoverers of either but as carriers of both. The fateful letter Bellerophon bore to Iobates was something graved in a folded tablet.[9] We know that the author of this line in the Iliad was familiar with the art of writing letters in very portable form and that marks, not by any means the first recorded instance possibly, but it marks an event pregnant with interest for the historian of the evolution of civilization. It has lain before the eyes of men for 2,500 years unrecognized before modern archeology was born. It may be said this is history only by inference, but it acquired significance when fifty years ago we had to accept Troy as a fact and its situation in sight of the rushing tide of the Dardanelles, where there must often have been a portage across land for commerce, has rendered a Trojan war, or many of them, almost a certainty without any other argument than the geographical one. It has needed the acquiescence, however, of

[9] Iliad, VI. 169.

Sir Arthur Evans[10] for us to accept the identification of Atreus, the father of Agamemnon, by Dr. Emil Forrer among the findings at Boghaz-Keu, dating him at 1240–1210 B. C.

Although by this time we have hardly needed the reference in the Hittite records to a real Atreus to convince us of a real Troy Miss McCurdy[11] has added to our satisfaction in slowly realizing that Homer has historical value by noting that the breastplate of Agamemnon[12] came to him from a Cyprus vassal of the Atreus named in the Boghaz-Keu records. It has however further interest for us here than the demonstration of the purely politico-historical value of Homer to find Miss McCurdy thinks of steel used in the armor. The shield was made of twelve strips of gold, twenty of tin and ten of some blue metal which may have been steel, but the fact that the Homeric Greeks knew how to harden iron into the cutting edge of steel is plainly set forth in the Odyssey,[13] for there the blacksmith gets the full virtue of the iron in the axe by plunging it hot from the fire into cold water. The process was evidently a familiar one, for the description forms an illustration to enlighten his hearers as to something else. He would never have used one unfamiliar to them in this connection. A much later date has been ascribed to the revelation of the magnetic attraction of a Magnesian stone, at least to the western world. The knowledge of the properties of meteoric iron in all probability goes far back in the history of primitive man. He added doubtless this magnetic function of it to its falling from the sky as a reason for worshipping it. In the Odyssey it is associated, as a metal hard to extract from the ore, with other metals, bronze and gold,[14] and elsewhere it is said "it draws men to it."[15] One can hardly doubt this is one of Homer's quiet jokes, recognizing it as in the class of the precious metals, but alluding to the magnetic power frequently found in sidereal iron. I can see no reason why Sir Richard Glazebrook[16] should conjecture its magnetism was not known to the western world until 600 B. C., two or three hundred years after Homer seems to allude here to it as "drawing men." Such species of humor is very characteristic of Homer, in the Odyssey at least, a play on words being often apparent even to the tyro reading Greek.

Getting back to the Phoenicians, however, as ocean carriers, we can realize the weight and bulk of such heavy merchandise would preclude the metal being familiar to Mediterranean men in the light vessels of the epoch, until its chief usefulness as steel set the pirate traders of Tyre and Sidon carrying this munition of war and instrument of the arts everywhere, and it seems very likely from the Homeric poems, coinciding with much other evidence, this expansion of its use began somewhat near the time of the Trojan war and was well developed when Homer wrote. Homer apparently knew of steel, but he knew too it was not much in use for weapons at the time the war raged around Troy. His hearers could no more be told Achilles used a steel-tipped spear than readers in 1926 could be told machine guns were used at Bunker Hill. The Phoenicians carried iron in Homer's day, because people everywhere were learning to put an edge on it. They had carried their account books, too. The supercargo with his scroll, checking off the articles as they were carried ashore, must have been an impressive spectacle to the untutored Pelasgian or the quick-

[10] *Journal of Archeology,* July–December, 1924.

[11] *Ibid.*

[12] Iliad, II. 19.

[13] IX, 392.

[14] XXI, 10.

[15] XVI, 294.

[16] SCIENTIFIC MONTHLY, March, 1925.

witted and unlettered Dorian, but recently come over the mountain passes from the north. The Phoenicians, however, stand out in the Homeric poems in a rather evil light. Homer, following the bad example of the Christians, later gives them a bad name, maligning them doubtless as underhandedly as those now taught to speak no evil of any man. The Phoenicians were Semites, perhaps Jews, and knew as well then as now how to beat the Greek at a battle of the wits, and the Greek poet in his heart cursed them. To us they are significant as merchants who spread the arts of civilization from the Orient bordering on the Middle Sea to the Occident even beyond the Pillars of Hercules, as far as the shores of Britain and no doubt beyond. It is not at all impossible they may have injected that faint reflection of Babylon claimed for the saga of the Nordic tribes around the North Sea. That the Phoenicians were Semites or of allied blood seems a rooted belief in archeologists. In the Odyssey the swineherd[17] tells a bad tale of his own undoing and it brands them as pirates and manstealers, but bold and unrivalled mariners. We get more than one reference to this sort of thing and we infer that the practice was not confined to the Phoenicians, for one of the haughty wooers exclaims,[18] angered at the words of the friends of the disguised Odysseus: "Come, let us throw these strangers into a many thwarted ship and send them away to Sicily where they will bring a good price." Mariners have always been a hard set and harshly treated ashore, liable to kidnap and liable to be kidnapped even in times not so very far back, but through them in Homer's time, when there was no flag for commerce to follow, civilization followed in the wake of pirates.

The Cretan and Phoenician merchant made piracy a part of his trade no doubt. Minos in his time is said to have checked the former, but it bloomed again in the time of Homer when the Phoenicians had succeeded the Cretans on the sea, or that seems likely as we interpret the Homeric poems in the light of modern archeology. The corsairs of England of the same ilk, though not of the same blood, so also those of the Barbary coasts for hundreds of years, were such merchants of the sea. All did it who followed the sea. Plato insists[19] not only has the sea brackish, bitter water, but it begets in the souls of men uncertain and unfaithful ways. "Naval powers, which owe their safety to ships, do not honor that sort of warlike excellence which is most deserving of honor." I suppose Plato had Homer's Phoenicians in his mind when he wrote thus, but that there were others, that a piratical turn of mind was characteristic of all seafaring men he knew is also evident from his generalization. Crime followed in their wake. Swift-going rum boats and swift-moving motors present now the same results from the same fundamental cause—superior speed and skill. They have always had a sort of credit with loose-minded people because of it, and Homer makes no attempt to hide the Phaeakians were pirates and yet had for sovereigns the most generous of kings and the most virtuous and the wisest of his women. Fine shades of distinction did not exist then and are still difficult to draw between big business and piracy. The greatest benefactors of the human race seem in the days of Homer to have been pirates. This is a queer world. Everything passes and everything remains the same.[20] In Hades meeting Agamemnon Odysseus asks him naïvely if he had been killed on his way home, burning cities, raiding cattle and raping women.[21]

In reading of the rich gifts with which Alkinous, the King of the Phaeakians,

[17] XV, 415.
[18] XX, 382.

[19] Laws IV, 705, 706.
[20] VI, 270, *seq.*
[21] XI, 402.

loaded Odysseus on his departure, in reading how richly Menelaus and Helen did the same for Telemachus returning home we have only to turn to modern stories of Bedouin sheiks and African chiefs, when Africa was none of it white, exercising the like munificence and hospitality. The wandering rhapsodes and minstrels of the Aegean and the shores of Asia extolled these virtues in their audiences for their own profit. They lived on the munificence and hospitality of a lot of pirates, booty and body snatchers, to whom valuables came and from whom they as rapidly went. The arts if not the sciences at their beginning flourished on rapine and we find them turning to heaven for their reward. "It is not my custom," says the swineherd even, "though I might wish the evil, to dishonor a guest, for before Zeus all are stranger guests and beggars."[22] I give to the poor that at least the gods may give to me. Modern man does not flinch before the "do ut des" proposition, but we get a clearer perception of the road we have travelled from primitive times in noting the absence of any uncomfortable allusion to "tainted wealth." Still more primitive and bordering now on magic, of which Homer is surprisingly free in his relations, we find even the slave as a token of respect or fear loath to mention his master's name.[23] Among primitive people we are still familiar with this and the hair and nails as part of modern primitive magic and voodoo. When the swineherd came to kill the pig[24] he cut the hairs from the pig's head and threw them in the fire and showed good sense in not forgetting the dead, for who knows how many ghosts may still be outside of Hades? This he did first and prayed to all the gods. Where magic leaves off and religion begins depends on the piety of the critic. We may infer it was a pretty small pig for a five-year-old from the way it was handled and slaughtered for a party of half a dozen men —and slaughtered on the domestic hearth! Was Homer a city tenderfoot? Very likely, for this sounds like some of his modern critics when they break into bucolics. There has been long discussion among the latter about one or two places in the Odyssey when it apparently speaks of the purple wool shorn from sheep. Did Homer nod here? Or was the original line so worded as to refer to the Tyrrhenian dye afterwards used? No, this time it is the tenderfoot critic. Wool shorn from the wrinkles around an old ram's neck or elsewhere where it is dense and thick, crusted with dirt on the outside and yellow and greasy next the hide, in there between one often does get a purplish tinge to the wool as clipped by the shears. It is a matter of iridescence and vanishes after the fleece is off. Homer may have referred to the dye afterwards used and the line is twisted or he may as a boy have stood close up and watched minutely the clipping of the wool, but the critics surely have never been nearby spectators.

But not to wander further we must stop to remember that the ancient citizen was far less a tenderfoot among the Homeric Greeks than among us. He was far more deeply versed and immersed in superstitious magic than the light-minded cynic of the cities to-day. Odysseus was famed for his wits and his acquaintance with men and affairs as well as for his religion. Considering in antiquity there was far less difference between the tenderfoot of the tenderloin and the back district rube, between gown and town, between king even and peasant than there is now, the student of ethnology need not be surprised to note that after Odysseus has been cast

22 XIV, 56.
23 XIV, 145, *seq.*
24 XIV, 420, *seq.*

ashore on Phaeakia from the frightful peril of the waves, succored by a fair and doubtless curious damsel, after he has penetrated a princely house and has been hospitably entertained, slept there, asked for and has been promised a safe conveyance home wherever it may be over the sea—after all this one may wonder he has still not told his name. Homer, nearer primitive man than we, is apparently so penetrated by this superstition he does not think he is called on for an explanation why Odysseus does not want to tell his name. It was not altogether magic doubtless which induced a stranger in a strange land to hide it. It is just possible he may not be so far from home as to preclude the possibility of his having an enemy who may find him unprotected now by its safeguards, but with primitive man, aside from all this, it is supposed for a man to reveal his name gives any evilly disposed person a handle by which to work his destruction through magic. Homer does not say so, he does not need to, he feels his audience will understand without an explanation.

Notwithstanding this greater levelling of enlightenment as between ranks, as between castes, Homer and Homer's readers were aware of the meaning of civilization. They too were very far from that lack of self-consciousness which is the aim of enlightened people, they were as full of it as the modern city dweller is of his provincialisms when he attempts to display his knowledge of the provinces. Even at the acme of his enlightenment the Greek habitually referred in opprobrious terms to the barbarian from whom he had but lately derived his origin and more recently his civilization. The Homeric Greeks were far enough along to know and define the primitiveness of primitive man, but in the time when Athens was mistress of the seas the contemporaries of Pericles were ever ready to "'eave a 'arf a brick" at the stranger if he was a barbarian. Reading in Homer the description of the environment of the Cyclops[25] we find they lived in a land where wheat and barley grew wild, from which we are privileged to believe that wild men lived off of wild grain in Homeric days, but wheat and barley had been domesticated probably thousands of years before Homer's time in Egypt and in Asia. The king of the Lastrygians was a cannibal, too, as well as the Cyclops.[26] Cannibalism then probably was not infrequent in the islands and around the shores of the Mediterranean in Homeric times, but that it already excited horror and disgust in Homeric audiences we may conjecture and, as has been said, we thereby perceive too how much nearer Homer was to the realism of primitive life than we and how to this, doubtless, he owes some of the immorality of his verse. For it has been pointed out by many before Professor Scripture[27] that the natural speech expression of the more primitive savages is unconsciously in verse form. That is how, as so many poets report, Goethe and others, their powers come to them. The source of the verse, like the source of essential poetry itself, is in a partial yielding of the self to the demands of the unconscious for expression. Again we see how it is Homer finds[28] nothing unnatural and Odysseus finds it quite a matter of course that the Phaeakians profusely shower costly gifts on him in the spirit which still lingers somewhat with African and Asiatic chiefs.

When we come to the slaughter of the suitors, so outrageous has been their behavior even the modern man feels a return of his savagery and gloats in antici-

[25] IX, 110.
[26] X, 116 to 124.
[27] *Nature*, December 6, 1924.
[28] VIII, 389.

pation of their discomfiture when the old tattered beggar springs to his feet and throwing off his rags reveals himself, the fatal bow in his hand, as the injured Odysseus. Every reader feels it, every critic. The interpolators and scholiasts have nearly ruined this part. They have made it absurd to the point of chilling the readers' glow of sympathy with poet and hero. Killing one hundred and eighteen men makes even a hero, without a machine gun, ridiculous, but it is not this that sickens the modern reader. He has lately made an ovation for the returning hero who has killed thirty-seven. It is not the number, it is the absurdness of the impossible, but beyond this there is something else. The modern man of peace revolted a little at presenting a farm to a man in this age of the world who had the blood of thirty-seven men on his hands and heaved a sigh of relief when he finally disappeared from public view, but we have progressed, or rather we have covered our souls with a little varnish since Homer's day. Deep down, in humiliation after the great war, we acknowledge, lies the bloodthirstiness of the primitive savage, but we have added the varnish. Let us not forget that. We can stand for the moment the slaughter of twenty or thirty men, all the critics seem disposed to believe existed in Homer's draft, but some of the details still sicken us, even cutting it down to this.

Revolting and acutely reminded of the savagery of primitive man, or perhaps sickened to think we too, deep down, have the lust for blood and the joy of seeing the sufferings of our fellow-men who have offended us—we are reminded of both when the hero who mounted willingly and gloriously to the couch of Calypso and enjoyed the favors of Circe hangs the serving women at home to the rafters for adultery and cuts off the nose and ears and feet and hands and genitals of Melanthius and throws them to the dogs.[29] This is war. He had instructed[30] the swineherd to tie up Melanthius by the neck to the rafters so his toes touched the floor that his death might be a lingering one, but now he was dead and that's the way the hero treated the dead body. That is war. Let us thank God after all for the varnish. No poet at least now sings such a tale as that.

We can scarcely bear to see it on the page here crowded in one short paragraph to make up the atmosphere of the Homeric Greeks, the environment of primitive men which lingered around them more obviously, but which lingers with us still. The killing of the wooers was so delicious a morsel the editors and interpolators who followed rolled the episode under their tongues, expanded it and added to it until they made the poor blind old poet ridiculous and his hero killing a hundred and eighteen men with a bow and spear they removed for the moment from human sympathy altogether. They repeated it by removing it to hell and telling it there[31]—it must be confessed a more suitable place. What still further interests us in our study of the social state of primitive man in the Odyssey is Odysseus saying[32] it is best for him to take to the tall timber after he had killed so many of the sons of the most distinguished of the islanders. We get the plain indication of the blood feud requiring, rather lamely, the intervention of Zeus and Athene to wipe it off the slate coming down with the thunder and the lightning.[33]

Miss Harrison has done so much to

[29] XXII, 470, 6.
[30] XXII, 177.
[31] XXIV, 179, *seq.*
[32] XXIII, 138–9.
[33] XXIV, 539.

collect[34] inferences which connect the classical conception of Zeus' thunder with the bull roarer of primitive man's magic, and her work is so well known it would be gratuitous to more than refer to it here in connection with the numerous thunderings in the Iliad and the Odyssey, but it may be added the primitive awe, still alert in Homer's day, must have made the situations where it is introduced vastly more horrific than is possible for the modern poet or novelist with their finest descriptions of disturbances of the weather. The actual thunderbolts of Zeus found their place with primitive men with more difficulty than the bull-roaring priest found in imitating his thunder, but according to Miss Harrison it seems likely the stone celts dug up in Homeric and classical ages were shown to awe-struck audiences as the missiles of Olympian Jove.

[34] "Themis, a study of the social origins of Greek religion," 1912; "Prolegomena to the study of Greek religion," 1903, Cambridge University Press.

# THE CONFLICT BETWEEN SCIENCE AND RELIGION

By Professor HORACE B. ENGLISH

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THOSE scientists who have been going about "crying, 'Peace, Peace,' when there is no peace" are performing a doubtful service to their mistress. The conflict between science and religion—who can say whether for good or ill?—is most real. Not the paltry conflict recently dramatized for us in an obscure mountain town. Not the conflict, sharp enough but unreal, between Syrian mythological cosmology and the hypothesis of organic evolution. To discuss that is unworthy of the intelligence of mature minds, though unfortunately often necessary.

The real conflict, as the fundamentalist probably dimly senses, lies much deeper. Religion is not, as the scientific compromisers seem to imply it is, something one assumes in church on Sunday and leaves in the vestry with the robes of the choir for the rest of the week. It is a way of life and a philosophy of life. But science also implies a way and a philosophy of life and the two ways are antagonistic. Preachers for unnumbered generations have been telling us that true religion must affect all that we do; but equally it must be affected by all that we do. The interpenetration is complete. How, then, can religion remain indifferent to, or unaltered by, science? Deeply rooted from the beginning in cosmology, how can religion ignore a science which finds in minute telescopic whorls of the Milky Way solar system upon solar system, each dwarfing our own into insignificance?

Think for a moment of the place of prayer in a world of science. It has become fashionable to call a certain type of meditation and self-communion "prayer." I do not mean to doubt the value of such spiritual exercise. It is explicable, though not yet fully explained, on psychological grounds. But this is not prayer. I mean by prayer what truly religious people have always meant by prayer, communion with the Divine. Such prayer is the very heart of religion. "Give us this day our daily bread." Yes, by grace of tractors, self-binding reapers, Minneapolis millers and modern transport. Fifty years ago men could in sober earnest pray for rain. That has passed; we read the weather reports. To-morrow we shall perchance look to the sunspots for our predictions and the day after to-morrow we shall make our own rains. No longer will the Lord make His rains to fall upon the just and the unjust; the rain will fall upon those who have the price. Few are left who invoke prayer for the healing of the sick, still fewer who can see in sickness and in health evidences of God's wrath and mercy. People still pray for strength to withstand tribulation and temptation, but as psychology comes of age as a science, that too becomes impossible. Man's moral life is seen as the inevitable outcome of heredity and environment. For a God displaced by science from the center of the physical universe, there is no shelter in the center of man's soul. To whom, then, shall we pray, and for what?

As science progressively takes possession of our modes of thought, religious modes become increasingly impossible. The end of this process will not come in our day. Scientific discoveries which

can be turned into utilities are quickly adopted, but there is a great lag in time between discoveries which mean new ways of thinking and their penetration of popular consciousness. We are just beginning to reap in common consciousness the fruit of the scientific revolution of Copernicus, Galileo, Kepler and Newton—a revolution nearly four hundred years old. The real fruit of that revolution lies not so much in certain astronomical beliefs as in an altered perspective towards life and natural phenomena. To believe in astrology, to accept comets as portents of coming events, to think of the lightning as the weapon of Jove's or Jehovah's wrath, all this becomes impossible when one has located the earth in its proper place in the choir of heaven.

Evolution in biology is now accepted by cultured people as a matter of course. But only a select few of the world's great intellects have been so thoroughly steeped in the notion that it affects all their thinking. Yet not till evolution passes into the folk-way and into the ordinary vocabulary of the common man will the Darwinian revolution take its place alongside the Copernican. As for relativity, probably no one thinks consistently in its terms. Yet little by little scientific thought is penetrating our logic and the common consciousness. In the end it will inevitably triumph. As it does so, religious ways of thinking recede. Already the "faith of our fathers, living still" has lost much of its power over the lives of men; less and less does it answer to vital needs.

It is a common contention of liberals that this age-long conflict between science and religion is a boundary struggle, a war for the possession of disputed territory. Religion, so the argument runs, has intruded itself into the field proper to science, science has dogmatized about religious matters. There is little doubt that this is a true reading of the history of the conflict between science and *theology*. But as soon as we realize that religion is more than theology, we find that the conflict instead of being eliminated is intensified.

For religion and science both lay claim to disclose truth. Their approach to truth, however, is not merely different; it is antithetical. Religion bases truth upon revelation, whether supernatural or mystic. It endeavors to derive truth from the character of Deity. Science, on the other hand, seeks truth only as it emerges from fact. There are differences of temperament, of course, among scientists as among other men, and from these differences spring more varieties of method than is commonly admitted by those of us who like to talk of the "method of science." The method of the individual scientist may be intuitive, imaginative, deductive or experimental and inductive; it is always empirical, always an effort to learn from and be guided by facts. These two approaches to the shrine of truth can not be reconciled; one or the other must go.

Is this to over-simplify the issue? I think not. A rigorous attempt has indeed been made to divest the concept of religion of all that is accidental and nonessential. Thus most religions have been authoritarian and this has been a source of offense to some scientists. But there have been heretics and mystics in every age who have resisted authority in the true spirit of religion. Authoritarianism is not essential in religion. Again, the scientist sweating for his little bit of truth is apt to feel that the attractiveness of religion for her votaries lies in the easy disclosure of "truth"; that, in short, religion is an escape from reality. But the road of the mystic to his revelation is often long and exceedingly arduous. That the appeal of religion is strong to the weary and the lazy is but an accidental aspect which we must eliminate from the discussion.

Equally we must eliminate non-essential virtues. Religion has so long been the foster-mother of morality that we tend to forget their separate origin and their different natures. The time has come when morality, buttressed by an increasingly scientific ethics, can stand without the support of fostering religion. Nor is social service religion. I believe that we have found the core of religion in its approach to truth. *Religion claims to possess divine truth or rather a divine way to truth. It can not give this up and remain religion. And science demands no less than the unconditional surrender of this claim to truth.* In this fact we find an unreconcilable conflict between science and religion.

* * * * *

Yet science is not and can not be the whole of life. It must indeed, like any vital human concern, permeate all life. But in the tapestry of daily living, it is but one part. The pattern of that tapestry will be infinitely the richer for the work of science, but it will fall to pieces if, as the other strands rot out, they are not replaced. Men seek not truth only but beauty. Men seek not facts only but their significance and value. Science knows nothing of significance in this sense of the word and is indifferent to values. The realm of values and the realm of facts, though they have concurrent jurisdiction over our acts, can not be intermingled. To be truly scientific is precisely to ignore valuations.

Though science is thus indifferent to the questions of significance and value, living men are not and can not be. Science itself is pursued because it has certain values. Throughout long ages it has been part of the task of religion to raise aloft the standard of values by which men might measure existence and human effort. This must remain when religion shall have perished.

Twenty-five hundred years ago herdsmen prophets in Palestinian deserts had a vision, incomplete and halting, but vivid: God cares, and so man has significance. Something of that vision is needed to-day. The universe is not indifferent! In the face of a cosmic vastness undreamt of by the ancient founders of religion, there are those who dare to assert the significance of man. Human toil and effort and suffering, human happiness and human aspiration after righteousness, these matter. It is these which give meaning to life.

Two very divergent questions will here be raised. Is this not atheistic? And is not this but religion under another name. We should not shrink from the designation, atheistic; belief or disbelief in God matters little. But the attitude we have described seems almost to imply a pantheistic position. To assert that the universe is not indifferent is nearly tantamount to supposing it to be alive. Indeed there seems room for belief in a personal God who shares with man a moral significance.

The second question is less easily answered. It is not wholly a matter of appropriate terms. Were that the case, there would be great practical advantage in abandoning the term religion in the hope of getting rid of the abracadabra of religion, of the endless theological disputes about matters of no present-day moment, of intolerance, of denominationalism and of the other patent evils which, though inessential to religion, adhere like tenacious parasites to their host. To relinquish all claim to be religious would be a cheap price to pay for leaving all these behind.

There is, however, a more fundamental reason for denying that this faith in man's aspirations is religion. Words are not perfect symbols like the x's and y's of algebra to which one may give what meaning one will. We may not lightly undertake to say all that may be meant by such a term, rich in generations of hallowed associations, as re-

ligion. But this seems clear: that religion means now, if it has not always meant, some sort of commerce with the Divine. The fundamental relationship, probably, as has been indicated, is the revelation of truth. Lacking this, a faith no matter how devoutly held as the meaning of life has little right to term itself religion.

The fundamental likeness to religion is not, however, to be overlooked. We have here to do, as in religion, with a faith. Not faith in God, to be sure, but faith in the validity of man's ideals. Such a faith contains within it the values which make religion precious to many forward-looking men. Undoubtedly also, it is religion which has historically promoted these ideals. Even the attitude of mind in which one holds this faith resembles certain religious attitudes.

Its advantage over religion in a world of science lies in its divorce from the claim to possess truth. From this faith in man no truth derives. Lacking this faith, we should not find the facts of life other than they are; they would merely be without significance. It is because this faith abjures all claim to empirical truth that it does not conflict with science.

That is, of course, merely a negative justification of one's faith in the significance of man. Is there no other? No, not if by justification be meant a rational process. Faith is never wholly justifiable by reason. What has reason to do with ultimate values, reason whose function it is to enable us to solve problems and to adjust ourselves to facts? The intellect is not the only side of life. At the heart of life there is an irrational element. I have faith in the nobility of man because I *will* have it so. I have faith in man because to live without it seems to me an incredible paradox.

Then there may be other faiths? Of course! And so long as they deal with values only and not with facts, each is as legitimate as the other. This faith I share with an increasing number of modern men. Will it create institutions, build churches, assemble dogmas? One can not say. But in this faith men will in all literalness as well as figuratively move mountains. In this faith men will live and strive. The source of values, not of truth, the complement of science, not its adversary, here is a faith worthy to take the place left vacant by a religious faith unequal to the conflict with science.

# ESTIMATING HUMAN CHARACTER

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THE divining of human character from external appearances has engaged the attention of man from the earliest periods of which we have record down to the present time. The Greek philosopher and guide, Aristotle, became quite encouraged over the matter and wrote a treatise on the subject of physiognomy. He was not the first to give serious attention to this inviting subject nor, by any means, was he the last.

To Theophrastus, the Greek of Eresos, a disciple of Aristotle, belongs the honor of having been the first writer of record to attempt a classification of humanity on the basis of character. At the age of ninety-nine, and, about three hundred years before the birth of Christ, this enterprising gentleman set about to crown his career as a student of human nature by providing posterity with a written record of his observations on the faults and virtues of humanity. But we have his words for it offered in that engaging style which has made his little volume, "The Characters," a classic, to wit:

> I have always been perplexed when I have endeavored to account for the fact, that, among a people, who, like the Greeks, inhabit the same climate, and are reared under the same system of education, there should prevail so great a diversity of manners. You know, my friend, that I have long been an attentive observer of Human Nature: I am now in my ninety-ninth year of my age; and during the course of my life I have conversed familiarly with men of all classes, and of various climes; nor have I neglected closely to watch the actions of individuals—as well the profligate as the virtuous. With these qualifications I have thought myself fitted for the task of describing those habitual peculiarities by which the manners of every one are distinguished. I shall therefore present to your view, in succession, the domestic conduct, and, what may be termed, the besetting practices of various characters. I am willing, my friend Polycles, to believe that a work of this kind may be beneficial to the succeeding generation, who, by consulting these patterns of good and evil, may learn, at once, to avoid what is base, and to assimilate their habits to what is noble; and thus become not unworthy of their virtuous ancestors.[1]

Who could have said better?

A study of the "Characters of Theophrastus" brings in its wake a disappointment, however, in the fact that the untimely death of this thoughtful observer prevented him from completing his task. Only the descriptions of the thirty non-virtuous types were ever finished. The analyses of the virtuous were thus lost to posterity and the world has since been left in doubt as to who Theophrastus really considered them to be.

We can not undertake the task of elaborating the story of the search for the hidden key to human character, for such would necessitate volumes. A few details refuse to be overlooked, however, such as the fact that the Greek writers prior to Aristotle explained differences in temperament by suggesting variations in the compounds of the four elements which they claimed as being the basic constituents of the human body, *i.e.*, earth, air, fire and water. Hippocrates (460–370 B. C.) denied this explanation and satisfied himself, at least, that humanity could be fitted readily into four types, namely, the sanguine, the choleric (bilious), the melancholic, and

[1] "The Characters of Theophrastus." Translated by Francis Howell; London, 1824.

the phlegmatic, depending upon the relative fluid content of the four bodily *humors*—blood, yellow bile, mucus and black bile. The Hippocratic grouping of temperaments as modified a few hundred years later by Galen became classic and can be found to-day with slight variations in many elementary text-books on psychology. The theory of bodily humors has been displaced, however, by the claim of certain modern physiologists that the secretions of the endocrine or ductless glands are the regulating factors in personality.

Vocational guidance through the interpretation of physical structure, one of the favorite money-getting devices of the present-day charlatan, was anticipated by Juan Huarte, a Spaniard, living in the century just following the discovery of America. Huarte petitioned King Philip II, of Spain, for permission to set up machinery designed to offer counsel to the wayward youth of the time. A part of his plea along with his basic thesis will bear repetition.

> Every man is born with a kind of particular disposition; each disposition and each aptitude correspond with a particular form of the head. . . . Thus it seems to me that it is requisite to set apart a number of sagacious and learned men, to examine and investigate into the mental qualifications and capabilities of young persons; in order to oblige them to make a choice of such sciences and professions as would be most in accordance with their intellectual constitutions; and not leave the matter to their own choice or direction. For in general cases, the choice will necessarily be an injudicious one and will induce them to give preference to some line of life which will prove less advantageous and useful to them than if they were under the direction of suitable and qualified counsellors.[2]

The father of most of the modern commercialized systems of character analysis was Johann Kaspar Lavater, a Swiss naturalist, who wrote an elaborate dissertation on "Physiognomy," published in 1787 in four volumes. Although phrenology was practiced by one Senor Rhazes as early as 925 A.D., it was not until Franz Joseph Gall offered his generalizations on phrenology in England during the early part of the nineteenth century that the public really became interested. The hold of his teachings, couched in the imposing terminology of the faculty psychology which was current at the time but which had really been suggested by Plato, upon the lay interest was equally as great as that achieved by the back-water of psycho-analysis during the present decade. The movement spread rapidly, reaching its height in America between 1840 and 1850. Among the group of ardent followers we find many historically famous names, such as Horace Mann and Henry Ward Beecher. Itinerant "professors" with trappings, usually including elaborate charts and models of the head with the areas of some thirty to forty human faculties demarked thereon, along with an occasional human skull, reaped a ready harvest from a gullible public whose members were awed by the profound knowledge concerning the human brain displayed by these "experts" and by the easy authority with which they read hidden secrets from the external contour of the head and face of each unsuspecting subject. Attempts of science to refute the dogmatic claims of these "skull-jugglers" availed little and it was not until some other novel idea caught up the public imagination that the movement died of its own inanition.

In spite of the historical death of the movement, it would not stay dead. The seemingly dead thing convalesced and gave evidence of a strong recovery shortly after the beginning of the present century. Rehashed systems based on the beliefs of the historical writers just mentioned are ever with us. We are invited to buy books which will teach us to judge people at sight. Employment

[2] Bernard Hollander, "In Search of the Soul," E. P. Dutton Co., 1920, p. 132.

managers are told that by using the system they can thereby select suitable men for each and every job in their business organization. One may also, it seems, sensibly choose a life mate by using these schemes of character analysis. Too the salesman is told just how to quietly size up his prospect before reaching the point of requesting a deposit on the first installment.

The proposition of detecting the hidden traits of personality is so extremely inviting and stimulates the imagination to such an extent that a part of the public is ever ready to respond. The proposition has an appeal equal to that of the philosopher's stone of the middle ages or of the "Doctrine of Signatures" of the early years of the modern era or of the alchemist's dream of the twentieth century—synthetic gold. In view of its wide appeal it is not surprising that the response required by the disseminators of this golden key to success, happiness and prosperity is the open pocket book.

Commercialized character analysis continues to be widely exploited. Many claims are made for it and equally strong criticisms are offered against it by practical men. In seeking to determine the truth, one finds further that pseudoscience has made exaggerated claims for the validity of modified forms of phrenology and physiognomy, while science has sought to confound the believers with citations of disproof in theory if not in fact. The resultant disputes, usually accompanied by rising blood pressure, have accomplished little by way of settling the point in question in the mind of the average man. Because of this confusion, the time seemed ripe a few years ago for a series of empirical experiments seeking to determine the validity or non-validity of the claims. Such a program was undertaken by the present writer and Dr. F. B. Knight at the University of Iowa laboratories in 1922.

Some of the most important results of the studies mentioned have been made available by earlier reports.[3] News reports and quotations in popular magazines have represented the results as giving evidence for the conclusion that *there are no external characteristics of the face or head by which the character of a person may be judged.*[4] In strict fairness such a statement is hardly warranted by the results, but it certainly does seem safe to say that *there are no fixed anatomical characteristics of the head or face by which character or personality traits may be estimated with a degree of accuracy such as is demanded by science or in reality by practical needs in every-day life.*

To illustrate one of the most common fallacies in attempting to judge character by external signs we may point out that attempts to judge intelligence by the size or shape of the head seem doomed to failure. Quality counts for more than quantity in brain structure. Extremes in physical structure sometimes give accurate insights into the intellectual quality of an individual, but it does not follow that an extremely small head denotes dullness, while an extremely large head denotes brilliancy of intellect. Extremely small heads are likely to denote low mentality, but so are excessively large heads. Some instances are on record of individuals having a fairly well-shaped head with practically no forebrain and as a result lacking almost entirely in intelligence. Neither may one, by way of further illustration, conclude rightly that a slim, wiry individual is likely to be quick and alert mentally and of an irritable disposition; that the fat man with a full round face is likely to be slow and deliberate mentally but of pleasant dis-

[3] *Journal of Applied Psychology*, June, 1924, Vol. VII, No. 2.

[4] *Hygeia Magazine*, April, 1925; *Literary Digest*, June 20, 1925.

position. Equally incorrect is the assumption that a brunette will become a steadier clerk than the supposedly erratic and temperamental blond. Isolated instances proving all these and similar claims may be found, but in taking large groups of people just as one finds them, exceptions will be found to be quite as numerous as the rule.

The evidence for such denials as those given above grows out of the experiments previously mentioned. The nature and methods of these experiments are described in the following paragraph.

Forty individuals, twenty men and twenty women, were used as subjects in the main experiment in this series. These persons were selected from among members of national sororities and fraternities in a manner designated to get as wide variations in temperament and ability as possible. In a series of measurements, including over one thousand major statistical computations, ratings by a large number of close associates on these men and women were secured covering character and personality traits such as *intelligence, soundness of judgment, frankness, ability to make friends, will-power, leadership, originality* and *impulsiveness.* Ratings by a large group of strangers on the same traits for the same group of subjects were also obtained. A third series of measurements were made following the lines laid down by the self-styled authorities on character analysis. The acquaintances were asked to rate the subjects so that their estimates would reflect the knowledge gained about the subjects through intimate association. The strangers were persons accustomed to employing people, such as business men, school principals, employment managers and others. The strangers were given an opportunity to rate the subjects only on short acquaintance and from external appearances. They were not permitted to interview the subjects. The measurements of the head and face claimed as important by the character analysts were made by means of carefully tested anthropometric instruments, the number of physical indices taken on each subject being somewhat in excess of two hundred.

The outstanding results derived from a critical examination of the ratings and measurements may be stated as follows:

(a) The acquaintances agreed closely with each other in their estimates on all traits listed above, except frankness and ability to make friends. Even on these two the agreement was fair.

(b) The ratings by strangers agreed with each other on all traits except frankness to a rather marked degree.

(c) The ratings by strangers did not agree with those made by the close acquaintances.

(d) The results secured according to the character analysts' recommendations did not agree with each other, nor did they agree with the ratings supplied by either the close associates or the group of strangers.

It seems safe to conclude that there exists only a vague and unimportant relationship between what one may determine from an examination of the fixed features of the head and face and the actual character of the individual. Certain other significant generalizations seem warranted by the data obtained to date:

(a) The relation to the subject of the person passing judgment on his character (friend, enemy, stranger, acquaintance, etc.) causes the estimate to vary widely, depending upon just what the relation happens to be.

(b) When a large group of persons all related to the subject in the same manner pass judgment on him, their estimates are likely to agree closely on some traits but vary on others.

(c) Strangers are more likely to be influenced by external appearances in their general opinions of the subject, but

they are unable to describe accurately just what it is that influences their opinions.

(d) Stranger's valuations of a subject's personal traits are likely to change rapidly as they become better acquainted with the subject.

(e) Individuals differ quite widely in their relative abilities to judge persons from external characteristics. The estimates secured range all the way from twenty per cent. accuracy to as high as seventy-five per cent. accuracy in exceptional cases. Those who are most accurate can not satisfactorily explain their method and in many instances deny that they have any set method.

(f) Training in observational methods of character estimation usually improves the abilities of the poorest judges, but reduces the accuracy of the best judges.

(g) Women are as a group able to form estimates of character from external appearances in just about one half the time taken by men. While men are more deliberative, they are usually just as accurate in their estimates as a group as women.[5]

An examination of all the evidence available seems to indicate that the general rule that may be accepted in any serious attempt to judge other people is that *behavior is a better guide to another's personality and character traits than physical structure.* The term behavior as used here is meant to include all such items as physiological changes in facial expression, gesture, posture, gait, speech, tone of voice, what one says and does in general in reaction to given situations. It must not be hoped that these behavior items will furnish an infallible guide to personality. All that can be said at present is that they may furnish the clues for estimates which may or may not later be verified by further observation of the individual being studied.

What, then, can be said of the future possibilities of judging character from external signs? Science may, after a long series of experiments involving the use of motion pictures and other quicker than eye instruments, be able to give us some solid facts for guidance. Present indications are that the results of brief tests, which depend upon "trying-out" people in given situations, are likely to provide the most reliable and authentic guides to character and personality. Still, there are many people who feel that they must trust to external appearances. To such persons the recommendation best given is to devote attention to observing *behavior* of others in relation to the environmental setting of the individual. It is possible to develop a sense of personal appreciation in somewhat the same manner as we learn to judge distances or learn to understand a language by living with a people who speak it. No system based on fixed features of the head and face is apparently sufficiently accurate to be of any particular aid.

[5] Conclusions (e), (f) and (g) follow citations by F. W. Allport, "Social Psychology," pp. 221–231.

# THE EEL IN ANCIENT AND MODERN TIMES

By RALPH C. JACKSON

Of all fishes, both ancient and modern, the eel, Anguilla vulgaris, deserves all the various conjectures and hypotheses which have been recorded in the pages of natural history. No fish ever enjoyed so wide a celebrity. Worshipped in Egypt, esteemed by the epicures of Rome and Greece, recognized by Hippocrates as a therapeutic agent, the life history of the eel baffled the scientific world for over two thousand years.

Eels are found in almost all fresh waters and seas of the temperate and tropical zones. In the United States they inhabit almost all streams of the eastern slope, but were originally wanting on the Pacific coast.

It may reasonably be assumed that no eel ever matures or spawns in fresh water. At this writing no one has ever captured a perfectly ripe female eel and all evidence at our command tends to show that the eel spawns in the sea, and like the Pacific salmon death takes place after spawning.

Eels in their fresh water habitat feed on fish eggs, insect larvae, frogs, and aquatic vegetation. It seems to be the consensus of opinion among fish culturists that the eel is the most voracious of carnivorous fishes. They are most particularly fond of our game fishes, especially trout and salmon. As a rule, eels are night feeders; in the daytime they are generally found in holes or beneath stones.

Meek and Jenkins are of the opinion that female eels grow to a much larger size than males and that the male does not exceed a length of twenty inches.

At certain seasons of the year adolescent eels leave the ponds and rivers and travel over land to enjoy other bodies of water. These migrations generally take place at night during a storm or when the grass is covered with dew. In 1914 the writer found an eel traveling through the wet grass four miles from any lake or pond. The above migratory movement of adolescent eels should not be confused with nuptial migration seawards, which takes place in the autumn.

Eels are divided into two types; yellow eels, which are eels before sex instinct develops, and silver eels, which are eels in their breeding costume. In some bodies of water yellow eels are not found in a well-nourished condition. The head is generally out of proportion, which gives them a weird appearance. In the autumn, the yellow eels take on a silvery coloration as they commence their migration seawards. The belly is a silvery white. The eyes are larger than those of the yellow eels and the gross appearance of the gonads show a change in structure and coloration.

A few years ago, certain Danish investigators working in conjunction with the International Council for the Investigation of the Sea tagged a number of eels to ascertain the number of miles covered during the migratory period. The records of recapture are most interesting. The rate of migration was found to be about ten miles a day. One particular eel covered a distance of seven hundred and fifty miles in ninety-three days. These experiments proved beyond a reasonable doubt the migration was seawards, as all the recaptured eels were found nearer the ocean.

The ancient naturalists knew nothing of the birth of eels. Oppian thought a

gluey substance detached itself from the eel and fell to the bottom and life evolved from spontaneous generation. Aristotle was of the opinion that eels were a solitary race that have neither seed nor offspring. Pliny believed that mature eels rubbed themselves to pieces against the rocks and produced a new brood. Van Helmont, 1635, attributed the birth of eels to the dews of May mornings, while other naturalists thought germination took place in the swim bladder and the intestinal tract. The ovaries of the eel were discovered in 1707 by Sancassini and later described by Valisneri. But it was only in 1873 that the tests of the eel were recognized by the Italian naturalist, Syrski, and shortly after described by Jacoby. The eggs were first discovered by Raffaele in the Gulf of Naples.

For over two thousand years it has been known that sexually developed eels move down the rivers and lakes in the autumn, on their seaward migration and in the early spring young eels or elvers move up the rivers in most countries of Europe. Up to 1896 the elvers or eel fry were the earliest stage of development known to the European naturalists.

In the Proceedings of the Royal Society of London, 1896, Grassi submitted a paper showing that the eel fry stage is preceded by a larval stage and that the little fish known as Leptocephalus are not foreign species, but the larvae of the eel. This minute fish was described by Kaup in 1856 as Leptocephalus brevirostris.

Of all oceanic researches of the twentieth century, the investigation of the eel by E. J. Schmidt, the Danish scientist, stands out preeminently in the annals of biological literature. After eighteen years of profound study, Schmidt elucidated the spawning of the eel. Schmidt found that the breeding grounds of the American eel, Anguilla rostrata, lie along the range north of the West Indies and that the breeding grounds of the two species are intermingled in the Atlantic.

During the larval stage the two species are differentiated only under the microscope. It seems to be the opinion that ovulation takes place with the American eel earlier in the season than the European species and as a result of this the American eel reaches the elver or eel fry stage in about a year. With the European eel, metamorphosis does not take place until the third year.

Schmidt (1922) summarized the breeding habits of the eel:

> Spawning commences in early spring, lasting to well on in summer. The tiny larvae 7–15 mm long, float in waterlayers about 200–300 meters from the surface, in a temperature of about 20° C. The larvae grow rapidly during their first months, and in their first summer average about 25 mm in length. They now move up into the uppermost water-layers, the great majority being found between 50 and 25 meters, or at times even at the surface itself. Then they commence their journey towards the shores of Europe, aided by the eastward movement of the surface water itself. During their first summer, they are to be found in the western Atlantic (west of 50 long. W.). By their second summer, they have attained an average length of 50–55 mm, and the bulk are now in the central Atlantic. By the third summer, they have arrived off the coastal banks of Europe, and are now full grown, averaging about 75 mm in length, but still retaining the compressed, leaf-shaped larval form. In the course of the autumn and winter, they undergo the retrograde metamorphosis which gives them their shape as eels and brings them to the elver stage, in which they move into the shores and make their way up rivers and watercourses everywhere.

*Courtesy of Swenson & Springer, Photographers, Springfield, Ill.*

FIG. 1.—IN THE WAKE OF THE TORNADO

ALL BUT THE STRONGEST STEEL STRUCTURES REDUCED TO A MASS OF TANGLED RUINS. PEABODY COAL MINE NO. 9 AT WEST FRANKFORT.

# THE MURPHYSBORO TORNADO[1]

By Professor W. O. BLANCHARD

DEPARTMENT OF GEOLOGY, UNIVERSITY OF ILLINOIS

On March 18, 1925, there passed through eastern Missouri, southern Illinois and western Indiana what press reports have described as the "deadliest tornado of American history." The storm track lay less than two hundred miles south of the University of Illinois, so that the writer, working in cooperation with the Graduate School of the university, was enabled to be on the scene of the disaster within forty-eight hours of the storm's passage. At that time the débris still lay where the elements had strewn it, and the impressions of the storm by those who had witnessed it were still fresh in mind. From the 20th to the 22nd, inclusive, the storm track was crossed and recrossed by the writer at as short intervals as the road conditions permitted, from western Murphysboro to some five miles west of Dale, *i.e.*, for a distance of over fifty miles of the storm's path.

The report which follows is based upon a record of the field observations, upon interviews with a large number of people living in the storm path or its vicinity who had observed the tornado's passage and upon the data furnished by the cooperative observers of the U. S. Weather Bureau and the Washington Daily Weather Maps for March 16 to 19, inclusive. I am particularly glad to acknowledge help given by Professor F. H. Colyer, Carbondale, and Messrs. Clarence J. Root and William E. Barron, meteorologists of the U. S. Weather Bureau, stationed at Springfield and Cairo, respectively.

## The Cyclone

The low pressure area within which the tornadoes of March 18 occurred probably originated in the region of the Gulf of Alaska, on March 13.[2] It appeared first on the Washington Daily Weather Map on March 16 near Calgary, Alberta. Its subsequent path, as well as the points reached at the end of each twelve-hour period, is shown in Figure 2.

Sweeping southward with increasing intensity, it reached the Oklahoma-Texas boundary on the evening of March 17. Here it made a right-angled turn to the north. On the morning of March 18, it reached a point just beyond Fort Smith, Arkansas, and during the following twelve hours there developed within it a series of five tornadoes. The path of the Low during that day led through southeastern Missouri, southern Illinois and western Indiana. Passing up the Ohio, it left the continent via the St. Lawrence Valley.

The part of the cyclone track mapped in Fig. 2 has a length of approximately 3,361 miles, which it traversed in eighty-four hours or at an average rate of forty miles per hour. The maximum rate of advance for any twelve-hour period was between Missoula, Montana, and Leadville, Colorado, where it reached a speed

[1] An investigation conducted under the auspices of the Graduate School of the University of Illinois, by whose aid the field observations were made possible.

[2] H. J. Cox, meteorologist, U. S. Weather Bureau, Chicago, Ill., in private communication to the writer under date of April 8, 1925.

Progress of the Cyclone[3]

| Date | Hour | City near center of Low | Progress in past twelve hours (miles) | Rate of advance in last twelve hours | Barometric pressure reduced to sea level |
|---|---|---|---|---|---|
| Mar. 16, | 7 A. M. | Calgary, Alberta | ........ | ........ | 29.62 |
| " 16, | 7 P. M. | Missoula, Mont. | 346 | – 28.8 | ........ |
| " 17, | 7 A. M. | Leadville, Colo. | 650 | – 54.2 | 29.62 (Denver) |
| " 17, | 7 P. M. | Altus, Okla. | 520 | – 43.3 | ........ |
| " 18, | 7 A. M. | Bentonville, Ark. | 365 | – 30.4 | 29.62 (Ft. Smith) |
| " 18, | 7 P. M. | Terre Haute, Ind. | 425 | – 35.4 | ........ |
| " 19, | 7 A. M. | Rochester, N. Y. | 530 | – 44.2 | 29.5 (Buffalo) |
| " 19, | 7 P. M. | Father Point, Quebec | 525 | 43.75 | |
| | | Total distance | 3361 | Av. 40.0 | |

of 54.2 miles per hour. During the twelve-hour period in which the tornadoes developed, the cyclone advanced at an average rate of 35.4 miles per hour.

By the evening of the 17th, the low pressure area had taken the form of a huge trough reaching from Ontario to Mexico. The isobars about the Low for 7 A. M., Wednesday, March 18, are reproduced in Fig. 2 from the Washington Daily Weather Map for that day. They show a striking resemblance in form to that of the generalized type favorable for the development of squalls and tornadoes, as shown in Fig. 3.[4] The

[3] Data from Washington Daily Weather Maps for the days indicated.

[4] R. DeC. Ward, "Tornadoes of the United States," *Jour.* Royal Meteorological Society, 43: 1917: 324, Fig. 5.

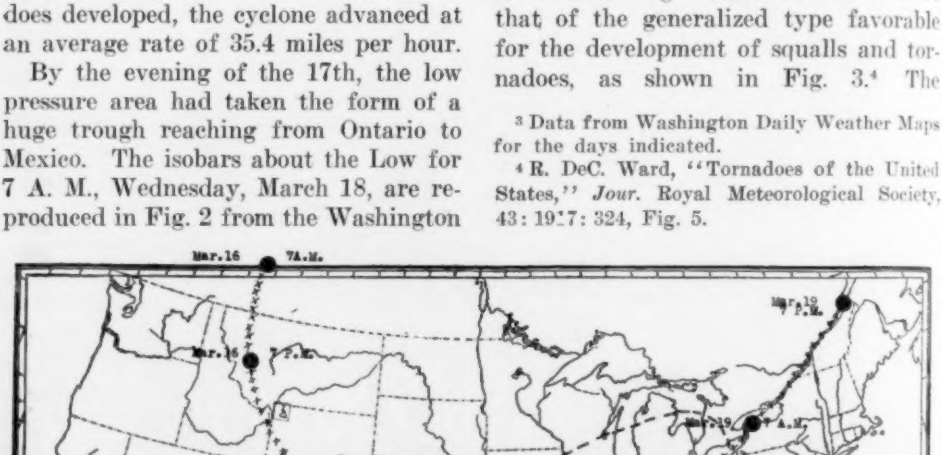


FIG. 2.—PATH OF THE LOW PRESSURE AREA
IN WHICH DEVELOPED THE TORNADOES OF MARCH 18, 1925. ISOBARS ARE DRAWN ABOUT THE LOW FOR MARCH 18, 7 A. M., CENTRAL STANDARD TIME.

V-shaped prolongation to the south, the axis of which represents the meeting place of the warm, moist winds from off the gulf, with the cold, dry winds from the north, is very well developed.


FIG. 3.—GENERALIZED LOW

SHOWING CONDITIONS FAVORABLE FOR SQUALLS AND TORNADOES. COURTESY OF R. DEC. WARD.

The records as reported[5] by observers along either margin of the tornado path confirm the existence of this condition. A study of the data given below shows a difference in temperatures, both maximum and minimum, between the stations north and those south of the path, considerably greater than is to be accounted for by the difference in their latitudinal positions.

[5] Private communications to the writer from U. S. cooperative observers at the places named in the table.

### THE MURPHYSBORO TORNADO

*Object of Field Observations:*

The field investigation was intended to establish as far as possible facts bearing upon the following:

(1) The path of the storm, its exact location, dimensions and continuity of earth contact.

(2) Movements, both progressive and rotational, their direction, velocity and the time required for the storm to traverse a given point in the path.

(3) Evidence of low atmospheric pressures, the bursting of buildings and strong updraft capable of lifting heavy objects.

(4) The weather conditions preceding, during and following the storm and the appearance of the storm itself.

(5) Damage done in different portions of the path, the effect of relief features and the relation of building construction to the protection of life and property.

*The Storm Track:*

The path of the tornado was unusual in many respects. As shown in Fig. 4,

WEATHER OBSERVATIONS ADJACENT TO TORNADO BELT, MARCH 18, 1925

*Points North of Tornado Path*

| | Sparta | DuQuoin | McLeansboro | Mt. Carmel |
|---|---|---|---|---|
| Max. temperature | 61 | 65 | 64 | 60 |
| Min. " | 43 | 42 | 45 | 46 |
| Wind direction | SE | NW | SW | NW |
| Sky | Cloudy | Cloudy | Cloudy | Cloudy |
| Precip. in inches | .16 | .77 | — | .40 |

*Points South of Tornado Path*

| | Carbondale | Harrisburg | Carmi |
|---|---|---|---|
| Max. temperature | 69 | 74 | — |
| Min. " | 48 | 49 | — |
| Wind direction | SW | SW | — |
| Sky | Cloudy | Pt cloudy | Cloudy |
| Precip. in inches | .82 | — | 1.02 |

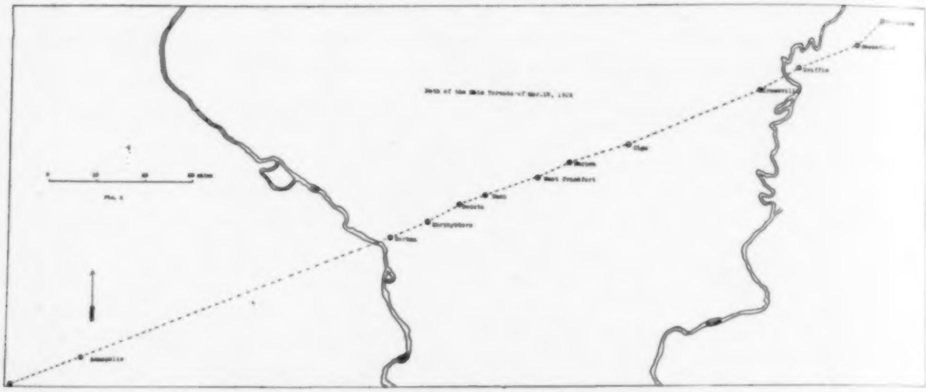

FIG. 4.—MAP OF TRACK OF THE TORNADO

it maintained a direction which varied but little throughout its entire extent. In Illinois it lay about 21° north of east. Though but slightly over two thirds of the length of the Mattoon tornado of 1917, it is about ten times as long as the average for this section. Throughout its entire length of about 220 miles, it never severed its contact with the earth. The total width of the path in the portion observed, furthermore, was maintained practically constant at about three fourths of a mile; that in which everything was practically all destroyed, at from one half to two thirds of the total. The breadth in Missouri is reported as being one fourth mile; at the other end of the path, it narrowed to that width only after the storm had reached a point one and one half miles beyond Princeton, Ind.[6] For over one hundred miles of the path, the width was maintained fairly uniform at about three fourths of a mile. The total area affected exceeded one hundred square miles, of which about fifty were completely devastated.

*Eastward Progress of the Tornado:*

The speed at which the storm swept eastward was unusually rapid. The actual velocity was determined by checking the time of the storm's arrival at the several cities and villages along the path. Since the route between towns was essentially an airline, the exactness with which the velocity could be computed depended upon the accuracy of the reports of the storm's arrival. Clocks which went down when the storm struck[7] or which stopped when the walls to which they were attached rocked and swayed[8] were sought for and their record kept if the owner could verify their accuracy. Office managers,[9] railway men and others who would be likely to know the time were sought and their reports checked against each other. The table on page 439 gives the data secured for points between Gorham, Illinois, and Griffin, Indiana.

The average forward movement is thus seen to have been almost a mile a minute. This was about 50 per cent. greater than in the case of the Mattoon storm in 1917.

*Duration of the Storm at Any One Point:*

Estimates of the actual duration of the storm at any one point were difficult to get from survivors. This was to be ex-

[6] C. J. Root, in a private communication to the writer under date of March 30, 1925.

[7] Murphysboro.

[8] Bush Y. M. C. A.

[9] Orient Mine No. 2, West Frankfort.

RECORD OF FORWARD PROGRESS OF THE TORNADO FROM GORHAM, ILL., TO GRIFFIN, IND.

| Place | Arrival | Airline distance in miles from preceding point | Speed in miles per hour |
|---|---|---|---|
| Gorham | 2:25[10] | ..... | ..... |
| Murphysboro | 2:32 | 8.5 | 73.0 |
| Bush | 2:47 | 13.4 | 53.6 |
| W. Frankfort | 3:00 | 11.8 | 54.5 |
| Parish | 3:07 | 7.0 | 60.0 |
| Griffin | 4:04[10] | 55.0 | 58.0 |

Total time, 1 hour 30 min. for 95.7 miles. Av., 58.0.

pected, of course, for in the midst of such a storm seconds may well seem like minutes. However, the period of duration may be computed, since we know the diameter of the whirl and the velocity of forward progress. Since the width of the path, and, therefore, of the whirl was about three fourths of a mile, while the forward velocity was about a mile a minute, it would take about three fourths of a minute for the storm to pass a given point. Estimates by observers ran as high as fifteen minutes.

*Criteria for determining Wind Direction:*

The wind directions at various points in the storm path were shown by the direction of fallen materials. Small wooded tracts or open fields strewn with débris were selected for study in preference to shade trees along city streets. Unsymmetrical trees or those likely to be deflected in their fall by telephone wires or whose roots may have been cut on one side for sidewalk or sewer construction, were passed over as unsatisfactory evidence. The woodlot just west of the high school at the western margin of Murphysboro and the open fields of corn stubble strewn with strips of siding west of the M. & O. tracks in the same city, the open fields and scattered trees of "The Camp" north of Bush, were types of places selected for observations.

[10] The time at Gorham and Griffin was reported in a private communication to the writer by C. Root, meteorologist, Springfield, Illinois, under date of March 30, 1925.

*Rotational Movement:*

That the chief movement of the air in this storm was rotational and therefore tornadic, there is no question.- Eyewitnesses and the evidence offered by damaged buildings and twisted trees furnished abundant proof. During the course of an examination of such evidence one came occasionally upon a case where the rotation seemed to have been clockwise, *i.e.*, contrary to the well-established law for rotating storms in the northern hemisphere.

FIG. 5.—CHURCH

FOUR AND ONE HALF MILES WEST OF DALE APPARENTLY ROTATED CLOCKWISE.

Fig. 5 shows a church which faces east and it will be seen that the rear end has been moved some fifteen feet to the north; the front end only five or six feet in the same direction. The building is located on the extreme southern margin of the storm track. Fig. 6 shows a frame house originally resting upon cement blocks. The structure has been turned 90°, the wing now facing east (to the left) was formerly nearest the point where the camera stood. Both buildings

FIG. 6.—HOUSE AT NEPERS CORNERS
THREE AND ONE HALF MILES NORTHEAST OF DALE. ROTATION APPARENTLY 90 DEGREES IN CLOCKWISE DIRECTION.

have been turned in a *clockwise* direction. Again in Fig. 7 there is shown a locust tree located near Parrish in which the twisting of the top would seem to have been the effect of a clockwise-moving wind. Though at first somewhat disconcerting, it does not seem at all unreasonable to find buildings moved as indicated. Such results may very well be due to differences in the rigidity with which the frame superstructure is fastened to the foundation. If, for example, the front portion of the church building had been rather firmly attached, a strong south or southeast wind in the tornado could easily turn it as shown. It will be noted that the whole building was moved north. The wind as shown by the fallen trees about Fig. 6 was from the north. If the northwest corner (on the right) was fastened rather securely, the movement would be as shown. An extreme case illustrating the same point was found in Murphysboro, where a filling station had been rotated clockwise, the building being turned upon the concrete tank in one corner which acted as a pivot.

FIG. 7.—LOCUST TREE
APPARENTLY TWISTED IN A CLOCKWISE DIRECTION. THE GRAIN WAS NOT STRAIGHT BUT SPIRALLY ARRANGED.

FIG. 8.—HARD MAPLE
ON 22ND AND SPRUCE STREET, MURPHYSBORO, TWISTED COUNTERCLOCKWISE. THE GRAIN IS STRAIGHT.

In the case of the tree in Fig. 7, it would seem entirely possible to produce the results shown if the original grain of the wood formed a spiral. A careful examination showed this to be the case, the

FIG. 9.—BUILDING ROTATED COUNTER-CLOCKWISE, MURPHYSBORO.

winding being clockwise, as may be seen in the upper half of the trunk. With such texture to start with, the splintered top blown over by a straight wind would appear to have been twisted in the direction of the grain. It should be remembered that the number of such cases was very limited, those whose movements were normal being vastly greater. The

FIG. 11.—HOME OF A. CRISP,
PARRISH, ILL. A 2 x 8 TIMBER DRIVEN THROUGH STUDDING NEAR CORNER.

FIG. 10.—RESIDENCE
ON EIGHTH STREET, MURPHYSBORO, SHOWING EFFECT OF FLYING MISSILES.

maple shown in Fig. 8 and the building in Fig. 9, for example, show a normal twisting.

The actual rotational velocity of the wind can only be estimated from the effects seen. Sticks and splinters without number were driven through pine siding of buildings. Fig. 10 is typical of walls left standing in the storm path. At West Frankfort a piece of 2 x 4 was

driven through the side of a coal car, fitting as tightly as though shaped by a cabinet maker. At the home of A. Crisp, Parrish, a piece of 2 x 8 yellow pine was driven through the siding, passing completely through a 2 x 4 oak studding and the end lodged against a second studding, as shown in Fig. 11. Straws driven into trees were reported near Crossville.[11]

The general wind direction and the location of the wind shift line are shown in Fig. 12. The arrows show the direction of the wind. It will be seen that the wind shift line lies about one fifth of the distance from the north margin of the path. The change from northwest to southeast winds along the line was very sharply marked—less than a block in width as a rule.

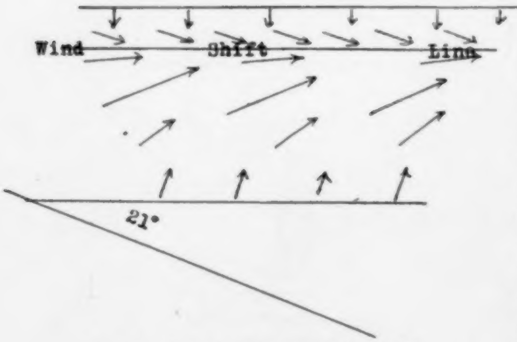


FIG. 12.—WIND DIRECTIONS IN A CROSS SECTION OF THE STORM TRACK AT MURPHYSBORO.

The great majority of the trees lay toward the northeast as shown. This was to be expected, of course, since this was the direction of the storm's progress. The velocity of the wind at any point in the path was the resultant of the rotational and the translatory movements. The velocity of the latter has been shown above to be about fifty-eight miles per hour. On the northern margin of the path then, the resultant would be the rotational velocity reduced by fifty-eight miles per hour; on the southern border it would be the rotational speed increased by a like amount. We have then not only four fifths of the width of the path south of the wind shift line but a velocity there which, at the extreme edges, should be 116 miles an hour greater than in the portion to the north. It is little wonder, then, that the main mass of débris was distributed as though blown from the southwest.

*Low Pressure in the Tornado:*

The extent to which the atmospheric pressure was reduced in the center of the tornado is, of course, not known. A barogram from an instrument one and one fourth miles south of the center of the storm track at West Frankfort is shown in Fig. 13.[12] The passage of the cyclone or Low across West Frankfort is shown by the broad V-shaped depression as occurring between 9:30 and some time past midnight of Wednesday, March 18. At 2:54, however, the needle dropped .23 inch, rising immediately the same distance and then rose gradually as the cyclone moved by. The drop of .23 inch recorded the passage of the tornado to the north. The record is of interest not only as showing a marked decrease in pressure entirely outside of the tornado path but as showing that the tornado at that place occurred simultaneously with the passage of the Cyclonic Low though the latter was probably centered north of the tornado. In most cases tornadoes have developed to the southeast rather than directly south of the center of the Low. The barograph at the Carbondale Normal, seven miles south of the path, showed no marked change which could be attributed to the storm.[13]

[11] Root, C. J., and Barron, W. E., "The Tri-State Tornado of March 18, 1925," Climatological Data, Ill. Section, March, 1925, p. 12d.

[12] Supplied the writer by Mr. J. E. Jones, of the Old Ben Corporation, West Frankfort, in private communication of March, 1925.

[13] Reported to the writer by Mr. F. H. Colyer, cooperative observer, U. S. Weather Bureau, Carbondale, Illinois.

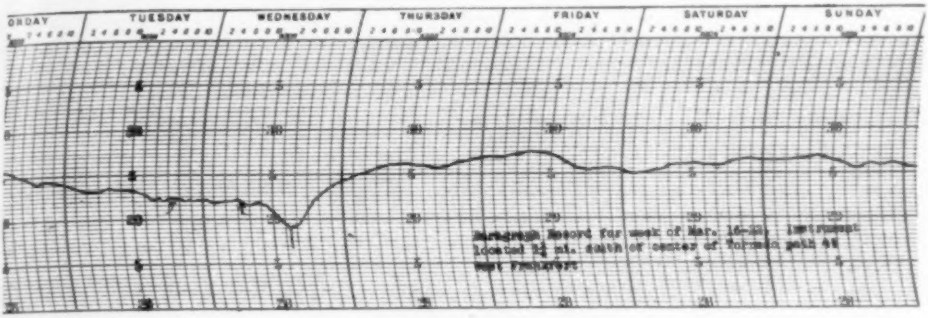


FIG. 13

THIS RECORD IS A TRACING FROM THE ORIGINAL LOANED THE WRITER BY MR. J. E. JONES, OLD BEN CORPORATION, WEST FRANKFORT, ILL. THE CLOCK STOPPED ON TUESDAY PRECEDING THE STORM FOR 12 HOURS (THE PORTION OF THE CURVE BETWEEN THE ARROW). THE INSTRUMENT, ACCORDING TO THE METEOROLOGIST OF THE U. S. WEATHER BUREAU AT CAIRO* WAS APPARENTLY RECORDING ABOUT .2 INCH TOO LOW. AS CORRECTED THE NEEDLE SHOWED A DECREASE IN PRESSURE DUE TO THE PASSAGE OF THE LOW TO 29.1 INCHES; THE TORNADO PRODUCED A FURTHER REDUCTION TO 28.87 INCHES. HOWEVER, THIS DOES NOT AFFECT THE FORM OF THE BAROGRAM.

* W. E. Barron in private communication to the writer under date of May 4, 1925.

FIG. 14.—RESIDENCE AT MURPHYSBORO
SHOWING PASSAGE OF CYCLONE AND TORNADO

Evidences of the low pressure in the form of exploded buildings were difficult to find. In many cases at Murphysboro, at least three walls identified as belonging to the same building had fallen outward. Fig. 14 shows a residence at 1912 Walnut Street, Murphysboro, in which the east gable-end, including the studding above the window, had apparently burst outward. The building appeared to be otherwise intact, except for windows and doors. Other types of evidence were not lacking. A shot-firer at Orient No. 2 said the forced ventilation system was non-effective while the storm passed. Many observers reported great difficulty in breathing during the worst of the storm. A cistern at DeSota, which had held eight feet of water, was said to have had but half that depth after the storm passed.[14] The disappearance of the house described by F. M. Hewitt, on page nineteen, was undoubtedly due to explosive violence.

[14] Reported by F. H. Colyer, Carbondale, in a communication dated April 29, 1925.

*Appearance of the Storm:*

The description of the tornado's approach by eye-witnesses varied with the position of the observer, the time of the observation and his mental state at the time. The rapid approach of such a huge death-dealing phenomenon provides conditions hardly conducive to calm and careful observation.

Of the many descriptions recounted to the writer, one seems particularly worth repeating. The observer, F. M. Hewitt, of Carbondale, occupied a vantage point at DeSota, directly in the path of the storm, which he first noticed when about three fourths of a mile to the southwest. He described the sky above the tornado as a seething boiling mass of clouds whose color changed constantly. From the upper portion, there came a roaring noise as of many trains. So definite seemed the source of the noise that it called for his remark to his two companions that the sound all seemed to "come from this upper part." Below this agitated, baggy-shaped mass of cloud, there was a tapering dark cloud mass reaching earthward. Lighter clouds flanked this dark mass upon either side. He estimated the width of the dark pendent portion as one fourth mile[15] where it touched the earth. As they watched the approaching storm in the growing darkness, a lightning flash showed a small house which a moment later disappeared as though dynamited. The three observers took refuge in a house which, when the storm struck, was dissipated, except a partition against which one of the party was standing. He was untouched, the other two were carried with the débris and one severely hurt. Mr. Hewitt was blown into the street, where he clung to a post until the storm had passed. He reported extreme difficulty in breathing for a period estimated at about twenty-five seconds.

Some of those who were in the storm path said they could distinguish no funnel-shaped cloud, others saw one or, in some cases, two which seemed to draw together from north and south and coalesce.

Thunder as of an approaching thunderstorm was heard, rain and hail fell, though not in excessive quantities. The feature which dominated the whole situation was the terrific wind filled with flying débris. A few rods to either side of the storm path, the most fragile structures, *e.g.*, huge signboards, were untouched.

It seems quite clear, from the numerous reports, that there was nothing of the dangling rope-like form suspended from the cloud canopy, such as is often seen to the west of the Mississippi. The dark mass reaching the earth was wider and much less definite in outline. The suggestion of C. J. Root[16] that the funnel cloud was so low as to resemble an inverted truncated-cone would seem to be an excellent one.

*Tornado Prediction:*

Tornadoes are often spoken of as "erratic," which means essentially that we do not thoroughly understand the detailed conditions giving rise to them or which control their action. In spite of their success in forecasting the normal changes associated with the passage of Highs and Lows, the U. S. Weather Bureau has never attempted to predict tornadoes. We know from a study of the records of such storms their areal and seasonal distribution, their association with the type of Low shown in Fig. 2 and their general direction of progress.

Their relatively rare occurrence, their limited period of existence, the restricted area covered and the conditions which control the direction taken, to say nothing of the reason why in some cases

[15] As indicated above, the path of essentially total destruction was two or three times the width.

[16] Root, C. J., and Barron, W. E., "The Tri-State Tornado of March 18, 1925," Illinois Climatological Data, March, 1925.

they skip about, lifting here and dipping to earth there[17]—all these are still problems remaining unsolved.

From a description of the tornado of March 18, it would seem comparatively simple to have sent word from the section first struck to the communities farther east. However, this tornado was unusual in its regularity. If all such storms moved as this one did in a fairly straight line for a long distance, keeping contact with the earth, maintaining a fairly uniform width and moving at a comparatively uniform rate, the problem of sending warnings ahead would be fairly easy. It seems, to the writer, that while we shall have to wait for more information before attempting a forecast, some system of warnings might be arranged to be sent after the storm had once appeared. If people had been on the watch they could easily have moved to the one side of the danger zone in three minutes, even if in the center of one of such unusual width as the Murphysboro storm.

*Relation of Tornadoes to Building Construction and Insurance:*

After a study of over five thousand tornado records, Lieutenant Finley concluded that it was useless to construct a building with the idea of making it strong enough to withstand a tornado. If one lived in a region frequented by such storms he advised the erection of tornado-caves or cellars and the spreading of the risk or loss of building by[18] insurance.

A report on this subject is now being prepared by a group of engineers from the faculty of the University of Illinois as a result of their study of the buildings in the path of the tornado of March 18. One of their number has stated as a result of preliminary computations that he believed buildings could be constructed to withstand such storms at a very small extra initial outlay. The bearing of such a problem upon the question of construction for protection of life, especially in public buildings such as schools, and the relation of such construction to insurance costs is obvious.

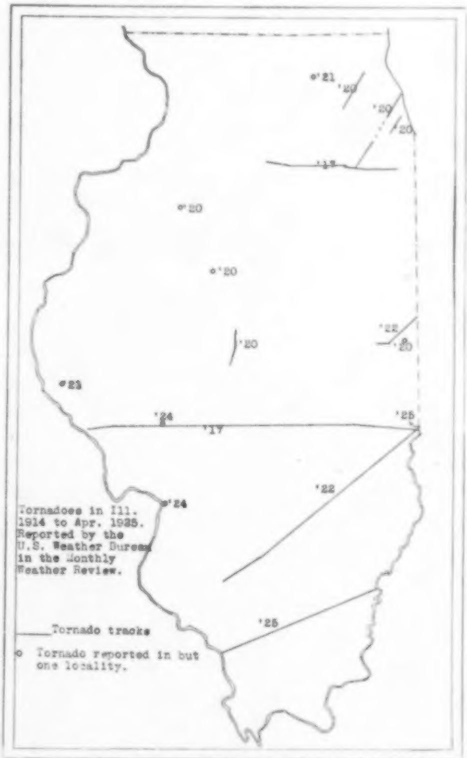


FIG. 15.—MAP OF TORNADO TRACKS IN ILLINOIS, 1914–APRIL, 1925.

An examination of the damaged buildings should show the necessity of having the floors forming the ceiling for the basement strong enough to bear the pressure of falling walls, thus serving as substitute for storm cellars. A remarkably large proportion of the buildings

[17] Note the tornado track through Will and Cook counties made in 1920. It seems quite probable that the disturbances in these two counties belong to the same tornado which lifted as it crossed Dupage County. See Fig. 15.

[18] Finley, J. P., "Tornadoes," *The Insurance Monitor*, New York, 1887.

destroyed had no basements. Resting as many of them did upon cement or wooden blocks, the wind had ample opportunity to get under the buildings and move them bodily. "The Camp," north of Bush, consisted of such light buildings. A glance at Fig. 10 shows the danger to which a person is exposed in the open spaces of a city or village.[19]

Fig. 15 is suggestive to those interested in tornado insurance. It will be noted that while the northern half of the state had about twice as many tornadoes as the southern, the latter because of the longer tracks have a much higher tornado liability. The bearing upon insurance risks and rates is obvious. Another aspect of interest to insurance companies is suggested by the map. In view of the general direction taken by tornadoes it would seem highly desirable for local companies insuring against tornado damage to spread their risks in a northwest-southeast direction rather than in a belt at right angles to this. Such a company confining its business, say to Jackson, Franklin and Hamilton counties, might be seriously embarrassed if not rendered bankrupt by such a storm as occurred March 18. It would seem highly desirable to map in great detail the frequency of tornado storms on the basis of the area devastated for as long as period as possible, as a basis for storm insurance.

[19] It is reported that a workman returning along the railway tracks from West Frankfort was overtaken by the tornado and took refuge behind one of the heavy plank posts used as "whistle" signals. Lying flat, face downward and clinging to the post he escaped serious injury, but his fingers exposed on the windward side were battered and skinned by flying missiles. Another less fortunate pedestrian took refuge behind the railway embankment, clinging to the rails to prevent his being blown away. Flying débris struck him, however, inflicting fatal wounds.

# RADIO TALKS ON SCIENCE[1]

## THE STORY OF THE NORTHERN ROCKIES[2]

By GEORGE R. MANSFIELD

UNITED STATES GEOLOGICAL SURVEY, WASHINGTON, D. C.

To him who in the love of Nature holds
Communion with her visible forms, she speaks
A various language.

THESE beautiful words of Bryant appeal with special force to the geologist because his business is to commune with the visible forms of nature and to try to understand her language. One of the most fascinating stories that she has to tell is to be read in mountain regions, where the rocks may be better seen than in many other places and where the exhilaration of living and climbing adds zest to pleasurable attempts at unravelling her many mysteries. Such efforts have a practical value for mankind, for in learning to read the story of the rocks much light is thrown upon the formation and distribution of valuable mineral deposits, useful supplies of water, or commercial pools of oil or gas. Ground is laid for the hope that we may in time abate the terrors and losses of earthquakes and of volcanic and other disasters of natural origin.

The story of mountain ranges like those of the Northern Rockies is not merely a record of a single great accident or convulsion of nature, or even of a group of such events. It begins in the remote past before there were any mountains at all in that region and continues into the future to a time when the mountains as we know them must be gradually reduced to lower hills or even be completely worn away. It is like a great and slow-moving picture, which we may look at for a time, but we are late in arriving at the theater and have to leave early. Although we actually see but a small part of the picture, we may from the evidence presented supply in imagination the parts that have gone before as well as those yet to come and thus gain a fairly accurate idea of the whole.

When we enter the Northern Rockies we are at once impressed by the beauty of their scenery. Here we note rugged cliffs of massive rock; there the valley sides retreat in gentle wooded slopes; here a stream tumbles noisily in beautiful cascades; there it winds slowly among brushy banks or in grassy meadows. Perhaps we catch the glint of snow on some of the upper peaks or see a glacier nestling in the shelter of a lofty ridge. Clouds hover in the sky above and their shadows chase each other among the valleys or are reflected from mirrored lakes. Their cooling shade refreshes the traveller after the heat and glare of the noon-day sun. These elements of the scenery are pages of the story we are following, so we must examine them more closely.

The rock ledges that first attracted our attention may be arranged in layers or beds, or may be crystalline or fine textured without noticeable bedding. The bedded rocks or strata are particularly interesting because in many places they preserve the remains of animals or plants; they may show current or ripple markings indicative of shallow water or of wave action; or they may contain cracks, footprints, or rain drop impressions like those now found in half-dried

[1] Broadcast from Station WRC, Washington, D. C., under the auspices of the National Research Council and Science Service and the direction of A. L. Barrows.

[2] Published by permission of the acting director of the Geological Survey.

mud flats. Elsewhere they consist of sands like those that now form dunes along our coasts or in desert areas; or contain gravels like those in stream beds. The presence of shells of sea animals in strata that are now thousands of feet above sea level shows that the mountains were built up at a place where once the sea had been. Similarly beds of coal or of cemented gravels in the same region show that the sea gave place to swamps or lowlands. Indeed as we examine the strata in detail we read in the successive rock layers that the sea advanced and retreated over this ground many times and that there were intervals when deserts, swamps, rivers, or even fresh water lakes occupied the country instead. As the geologist measures the thickness of the beds exposed to view he finds that the total runs into many thousands of feet. For example, in southeastern Idaho the thickness of the sands, muds and oozes now consolidated into rocks is about 46,000 feet, or more than eight miles. Since these beds were all laid down on what was then the sea bottom, or the surface, it follows that there must have been a progressive sinking of the ground while deposition was going on else these areas could not have continued to receive from neighboring lands such thick masses of sediments.

The rock layers are no longer nearly flat, as they doubtless were when first formed, but are now bent, twisted and broken in many places, thus furnishing evidence of former tremendous forces acting horizontally within the crust of the earth. Acquaintance with these mountains and with other regions brings out the fact that the earth is gradually shrinking in volume and that its outer crust is constantly being squeezed like the skin of an apple drying up. At repeated intervals the accumulated pressure has been too great for the rocks to resist and they have been crumpled into mountain chains in different parts of the earth. Mountain-building may therefore be said to be one of nature's habits. The favorite places for such events to happen have always been where muds and sands and other sediments have been laid down in greatest thickness. It is believed that at such places the crust is progressively weakened as the sediments gather and that the position and distribution of these strata in some way determine where and how the mountain-building forces shall act.

A contributing element in the process is undoubtedly the intrusion of great masses of molten rock, which have later crystallized on cooling underneath or within the strata. These intrusions have acted in some places like great hydraulic jacks in moving parts of the earth's crust.

Each movement or break in the rocks produces jars or tremors that we call earthquakes, so that it is natural that such disturbances should be associated largely with mountain regions. In fact their relative frequency is an index to the rate of growth of mountain chains. Thus the greater number of earthquakes in the Pacific Coast Ranges than in the Northern Rocky Mountains indicates a more rapid rate of growth in the former mountain group. On the other hand, the Montana earthquakes of 1925 demonstrated that mountain-building activity in that region has not wholly ceased. People are now living, traveling and carrying on the business of life in the coast region of California apparently unmindful of the fact that mountains are growing beneath their feet. Indeed the work of building mountains goes on so slowly that the average man in his lifetime may recognize few changes. Although careful instrumental measurements in the Coast Ranges have shown that crustal movements are in progress there, many centuries must elapse before the general appearance of the country will be much different from what it is now. Yet it is probable that the present rate of growth of the Coast Ranges is as fast as that of any of the mountain ranges that have formed in the past.

The crumpling of the strata into folds has been accompanied in the Northern Rockies by breaks in which great masses of folded rocks have been shoved bodily eastward over other masses, like one great ice cake upon another, for distances as great as 25 or 30 miles and along fronts ranging up to more than 250 miles in length from south to north. Such great breaks are called overthrusts. Individual overthrusts have been known in different parts of the Northern Rockies for many years both in the United States and in Canada. It is now being realized that these overthrusts are related to each other and that the earth's crust in the Northern Rockies has been piled in great slices with astounding horizontal movement and with total length probably approximating 1,000 miles.

It has long been known that the earth's crust is in a state of comparative balance, so that when any part of its surface receives a great load it tends to sink, while by some compensating change within the body of the earth neighboring areas tend to rise, much as if the earth's surface were a great pair of scales. It is therefore evident that when enormous masses of rock are piled up on the earth's surface by mountain-building agencies, the areas receiving such loads must tend to sink until the balance is restored. Thus the Northern Rockies with their folded and broken strata rising several thousand feet above the plains on the east must have overloaded the earth's crust when they were being piled up and must have sunk with the crust a certain distance during the restoration of balance, and hence are not so high as mountain-building alone would have made them.

Thus far we have centered our attention on the rocks, but the streams, snows and glaciers, which are parts of our mountain scenery, and the changes in temperature which we experience there have their part in the story. Their combined action is to loosen and remove pieces of rock, ranging in size from the finest flour-like grains to great boulders weighing several tons or even to landslides comprising thousands or millions of tons of rock debris. This material slides down by its own weight or is washed into the streams and is gradually removed from the mountain region altogether. Much is also carried away in solution. These processes, which we summarize under the terms weathering and erosion, are important factors in controlling the height of mountains.

No sooner do infant mountains rear their heads above sea level than they are attacked by winds, rains and other atmospheric agencies which tend to wear them down. The height which the mountains attain, therefore, gives a measure of the relative rapidity of work of the mountain-building and erosional forces. In the earlier stages when the agencies within the earth are more active the mountains increase in height. When these agencies slacken or cease, erosion continues and the mountains are slowly but surely reduced to lowlands. In the Pacific Coast ranges already mentioned growth is more active than erosion. The Northern Rockies are probably in mid career, with erosion perhaps slightly gaining. The Appalachians on the other hand are in the declining stage, when growth has practically ceased but erosion is still vigorous.

A mountain region that has passed through one long period of growth and decline in the manner just outlined may by renewal of activity within the earth be slowly lifted up again, and started on another similar course. Most mountain regions have had this experience and some of them have had it several times. Thus the history of a mountain region, which may appear simple in its broader outlines, becomes complex when it is studied in detail.

The Northern Rocky Mountains have been largely shaped by the sculpturing action of streams and glaciers, but the erosion has been guided by structure,

that is, its action has been selective among harder and softer rocks. The rocks that comprise the great overthrust blocks are generally more massive and more firmly consolidated than those of much of the over-ridden country. The overthrust blocks therefore in many places serve as protective cappings for weaker rocks that are elsewhere worn down or removed. Valleys that are deep enough to cut into the weaker rocks below the cappings afford opportunities for the geologist to identify the overthrusts, where the two kinds of rock are in contact, and to follow their courses across country. A particularly good place to see an overthrust, and one accessible to tourists, is the peak known as Chief Mountain in the northeastern part of Glacier National Park. This remarkable mountain, which is quite appropriately named, stands out in front of its fellows and faces the plains much as an Indian chief might have done in the early days. Chief Mountain is composed of very ancient, hard and massive rocks, mounted on a pedestal of weaker beds, which from the fossils they contain are known to be hundreds of millions of years younger than the overlying beds and are similar in age and character to those which underlie the neighboring plains.

I hope that any of my hearers who may chance to go to Glacier National Park will visit Chief Mountain, note the presence of the overthrust near its base, and try to read for himself the chapter of the story of the Northern Rockies which is there so clearly recorded.

# THE STUFF THAT THINGS ARE MADE OF

By Dr. CHARLES E. MUNROE

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THERE is no desire more universal among mankind than that of wishing to know what the things they encounter are made of. This desire is manifested in infancy; it persists throughout life. Every one has seen a baby reaching out to everything about it and testing everything it encounters by feeling, viewing, smelling and tasting, thus acquiring a knowledge of its form and properties. It is amazing how rapidly an infant learns through these explorations. If only each of us could have maintained through life the interest and power we possessed in infancy, and could remember and recall all we learned at this rate throughout our life, what a learned person each would be.

Watch the progress of those about you from infancy to the grave and you will witness in miniature a moving picture of mankind and its development from its infancy to its present condition. In the early days mankind tried, as the infant does, to distinguish things by their external appearances, characteristics and behaviors, but what a herculean task it was, for, consider vegetation, the multitude of varieties of grasses, of annual and perennial plants, of shrubs and trees; the multitude of varieties of fish in the waters and of insects everywhere; the innumerable micro-organisms; the great number of different animals and reptiles; the large number of different minerals; and the myriad of heavenly bodies. And consider further that no two things in nature are identical. There are no two leaves on the same tree that are precisely alike.

Yet from time to time men have been born with one or more senses especially well developed; a superior eyesight, a special delicacy of touch, a marked acuteness for sounds, or a sharpened sense of taste or smell which enabled him to note differences in the taste or odors of things that ordinary beings fail

to detect. Persons so blessed no doubt reported to others the results of their observations, whereby a body of knowledge was accumulated upon which the philosophic could speculate.

It is amazing how far man went under these conditions. He early practiced agriculture in its many ramifications, though agriculture is perhaps the most complicated and intricate of all arts and industries and one to which a wide variety of sciences contribute. He early noted and employed fermentation, for the Bible tells of Noah's indulgence in wine. Metals, such as gold, silver, iron, tin and copper, were early recognized and used. We were taught that Tubal Cain wrought iron. Colors, such as indigo, were extracted from plants, or, like Tyrian purple, from shellfish, and used in dyeing. Soap-making, another chemical industry, was practiced by the ancients. Naturally then as now there were inquiring minds that sought to know what things were made of and after much speculation, before the time of Christ, and for many centuries after, it was held that there were four elements—earth, air, fire and water—from which all things were made.

When, however, in the fifteenth century, A. D., men began to notice that chemical changes in matter were accompanied by changes in weight and, especially when in the eighteenth century Lavoisier taught the importance of making precise weighings and measurements in the study of matter, man began to perceive that there exist two great and easily distinguishable classes of matter, known, respectively, as simple or elementary matter and as compound matter. The different substances classified as elementary matter are also spoken of as elements, or more precisely as chemical elements. All the countless number of compound substances in nature are built up from the chemical elements.

While the number of compound substances possible is infinitely great, the number of elements is believed to be but ninety-two. The number recognized from the study of matter by many chemists through the use of the most delicate instruments and the most precise methods is now about eighty-eight, so there are some four yet to be found.

Elements have been found through searching everywhere on the earth, under the earth, in the oceans, in the air and on the far-distant heavenly bodies. The ancients discovered the obvious ones. Those like yellow, glistening gold or white, brilliant silver were among the earliest to be discovered. In fact, all those known to the ancients, though not identified as elements, were of the kind that occur *native*. They enter into combination with other elements, yet they are such they can exist free and uncombined in nature in the presence of all the other elements and compounds about them. The majority of elements can not do so, for they are very active and so eager to enter into combination they do not occur free, except as the combinations are resolved and the bonds severed by the chemist in his treatment of their compounds.

However, not all the elements that have from the beginning existed free in nature were recognized by the ancients. Though man from the beginning has lived in constant contact with them, although his continued existence was dependent on his continued use of some of them and although he, in sailing his vessels, in using his windmills, in seeking shelter from the hurricane and the cyclone, admitted their existence, yet because this medium, the atmosphere which surrounds our earth and contains these elements, is invisible, man for countless centuries failed to recognize it for what it is. Like a child of to-day he early recognized solids and liquids, but matter in the gaseous form remained a mystery until some one thought of trapping a portion of it in a vessel and studying its behavior under controlled conditions and with chemical reagents when promptly

an immense amount of new knowledge of nature was acquired.

In 1774, tens of centuries after man had recognized gold, Priestley, by means such as have been described, discovered the element oxygen freely existing in the air. It also is found existing combined in a very great number of different compound substances. In fact, if we take the data from the analyses of the different mineral substances occurring on our earth to a depth of one half mile, in the waters on the earth and the atmosphere surrounding it, oxygen proves to be by far the most abundant of all the chemical elements, and from many standpoints we may fairly say it is the most important of all, though each one has its specific duty to perform and all are essential to the completeness of the universe and the performance of its functions.

On September 5, 1926, on the occasion of the Golden Jubilee of the American Chemical Society, chemists from all over the United States, and many from foreign countries, made a pilgrimage to the grave of Priestley, at Northumberland, Pennsylvania, to do honor to the memory of the discoverer of oxygen.

As the nineteenth century unrolled, the minds of many seemed to have quickened and powerful instruments and devices for research into matter were invented. Of these the spectroscope, through which light could be separated and analyzed, was of the first importance.

Man had long recognized that there were many elements which imparted colors to flames in which they, or compounds containing them, were heated and he had, for some centuries, been using them in fireworks for amusement, though, in recent times, they have been applied to the protection of life and property on railroads and on the waters.

Thus sodium imparts a strong yellow color to a flame; barium, a green color; strontium, a crimson color; and so on. Now, behold! when these flames were viewed through the spectroscope, because of the form of the instrument, the colors appeared within it as colored lines, which always appeared in precisely the same place in the field of view. By examining the spectra of the various elements, it was found that each element produced a characteristic spectrum that was all its own and different from that of any other element.

With the development of spectrum analysis chemists found they had been put into possession of a method of analysis which, in its capacity to detect extremely small quantities of substances, vastly surpassed any method previously known to man. For instance, Swan found he could detect the presence in a flame of the 2,500,000th part of a grain of sodium.

Naturally, with such means at command, chemists began actively to reexamine the matter about them and soon additional elements, such as caesium, rubidium, thallium and indium, which occur in but quite small quantities, were discovered. Not content with a knowledge of the things on this earth spectroscopes were pointed to the sun and other heavenly bodies, and these were found to also be made of such elements as this earth is. Helium, which we now obtain from natural gas, and with which we fill our military dirigibles, was discovered by Lockyer, in the atmosphere of the sun while viewing a solar eclipse through the spectroscope.

Later in the nineteenth century, because Becquerel had observed that certain minerals photographed themselves upon a photographic plate even when both the mineral and the plate were in the dark, Madame Curie was led to examine such minerals with an electroscope, which is an even more searching instrument than the spectroscope, and by proceeding quantitatively, weighing and measuring, she discovered radium and other elements having radioactive properties. When the therapeutic value of radium, in the treatment of cancer

and other diseases, became known and a supply of it, for such uses, was sought, it developed that this element occurs, at least on the surface of the earth and to easily accessible depths, in extremely small quantities, and this furnishes one explanation as to why, through all the ages, this constantly glowing element had remained unknown to man. It is by means such as these the number of known elements has been brought to eighty-eight, the last announced discovery being that of Illinium, due to the cooperative researches of chemists at the University of Illinois and the U. S. Bureau of Standards continued over a considerable period of years.

The discovery that all chemical changes, either in building up a compound from its elements or in separating a compound into its elements, were accompanied with a change in weight, was one of the first importance, especially since it was later found that for any given element this was always perfectly definite in amount, for this led to the belief that this weight attached to a unit portion of each element. Through this, and other evidence, chemists, in the last century, adopted the atomic theory, which taught that all matter is made up of atoms of elements which are built up into molecules, in which the properties of bodies inhere and that these molecules are assembled to form the masses we commonly encounter and recognize. It was further believed that the atom was the smallest portion into which elementary matter could be subdivided and that by no means could the atom be further subdivided.

By comparing the weights of the known elements, and of others as discovered, with that of one of them, taken as a standard, the atomic weights were determined and these weights were used throughout chemical calculations for the control of extensive industrial operations, for the settlement of important financial transactions, in fixing the guilt of one charged with murder and in a great variety of other ways with entire acceptance. In fact, by classifying the elements according to the ascending order of these atomic weights, it was found possible to fix the places of those yet undiscovered and, more wonderful still, to predict the properties such elements, yet to be discovered, would possess, and elements subsequently discovered did possess the properties thus predicted for them.

The belief that an atom was an independent, indivisible entity, composed of the same kind of matter throughout, was generally accepted at the opening of this century. But Madame Curie, through her discovery of radioactive elements, had set investigators to observing how matter behaved when exposed to rays from these and other sources, and soon Rutherford announced to the world his having, by such means, not only knocked portions off of atoms but obtained other kinds of atoms, thus achieving for the first time the long-expected transmutation of elements.

Since the discovery of X-rays it has been known that they can penetrate deeply into matter and disclose its interior. By combining the X-ray with the spectroscope the interior of atoms has been explored, and from the information gathered it is now held that atoms consist of systems, analogous to our solar system, each with a central nucleus (its sun) containing protons, with other particles, called electrons, revolving like planets about the nucleus, and that all is electricity, the protons being positive and the electrons negative, and that one atom differs from another by the number of protons and electrons in its system.

A consequence of this view is that all elements, the molecules they form and the masses built up from their molecules are evolved from a single source. Hence, everything in the universe, including man, has been evolved from the same source, and the difference between the different things that exist is one, not so much of kind, as of number and arrangement.

# THE FOOD SUPPLY OF CHINA

By Dr. SHIH TSIN TUNG

THE frequency of famines as well as the prevailing standard of living in China would suggest that there is a serious food problem in that country. But this problem has never received more than local and temporary attention from the people who are really concerned with it. No accurate inventory has ever been taken of the amount of food produced each year or the land area available for food production. It is therefore impossible to launch any intelligent program to solve this fundamental problem of humanity.

However, it should not be too hastily inferred from the above statements that "China is an awfully crowded country." Whether China is overpopulated or not depends upon how the situation is interpreted. To begin with, we may compare the density of the population of several countries, including China, as follows:

| Countries | Number of inhabitants per square mile |
|---|---|
| France | 185 |
| Germany | 239 |
| India | 226 |
| Italy | 341 |
| Japan | 382 |
| Russia, Europe | 54 |
| United Kingdom | 389 |
| United States | 36 |
| China | 104 |

The population of China, although much denser than that of the United States and Russia, is not so dense as that of Japan, India and some European countries. China, therefore, is not overcrowded at all when her whole territory is considered. However, the actual condition is different. The great majority of the people live in the interior parts of China, which constitute only a little more than one third of the entire area. So the actual density is much higher, being 268 persons per square mile in the 18 provinces where most people live. Even this figure does not show the whole picture of the actual condition, because the average must have been pulled down considerably by the much lower figures of the northwestern and southwestern provinces which, being exceedingly mountainous, are but sparsely inhabited. The population of a few provinces is extremely dense, being as high as 875 per square mile in one case and 600 in another. When it is remembered that most of the people obtain their living from agriculture, and that each province being as large as the average European country and being inadequately supplied with transportation facilities, food is not easily obtainable from outside, it will be realized that the pressure of crowdiness must be severely felt in some localities. A study of the changes of the population in the past discloses the fact that the burden of overpopulation has been on China since a long, long time ago. The four-hundred-million mark was passed as far back as 1842 so far as available statistics show; since then the number has probably never markedly increased. The following table compiled from various sources will illustrate the extremely fluctuating nature of the population of China.

If the above data are reliable, reductions of millions and even tens of millions of people occurring within short periods appeared to have been a common thing. Certainly there are more causes than one

THE POPULATION OF CHINA AT VARIOUS TIMES

| Year | Number, 1,000 |
|---|---|
| 755 A.D. | 23,000 |
| 1014 | 22,000 |
| 1097 | 33,000 |
| 1195 | 48,000 |
| 1393 | 60,000 |
| 1381 | 59,850 |
| 1412 | 65,377 |
| 1580 | 60,692 |
| 1662 | 21,068 |
| 1668 | 25,386 |
| 1710 | 23,312 |
| 1711 | 28,241 |
| 1736 | 125,046 |
| 1743 | 157,344 |
| 1753 | 103,051 |
| 1760 | 143,125 |
| 1769 | 203,916 |
| 1761 | 205,293 |
| 1762 | 198,215 |
| 1790 | 155,250 |
| 1792 | 307,497 |
| 1792 | 333,000 |
| 1812 | 362,467 |
| 1842 | 413,021 |
| 1868 | 404,947 |
| 1881 | 380,000 |
| 1882 | 381,309 |
| 1885 | 377,636 |
| 1897 | 410,000 |
| 1909[1] | 439,214 |
| 1910[2] | 342,639 |

for such extreme cases of depopulation, but the lack of the means of subsistence was undoubtedly one of the most important factors.

In dealing with a subject like the present one, the use of statistical figures is almost unavoidable. As the Chinese government has never been able to engage itself in the peaceful undertaking of collecting complete and reliable statistics of its agriculture, it would be vain effort for the author to pretend the absolute accuracy of whatever figures he might use in connection with this article. But since we can not wait until the government can give us more accurate data and since nobody can do better at present than deal with rough estimates, the writer can be excused for presenting this paper. Of course he will exercise the greatest care and discretion in adopting the figures. In case of doubtfulness he will frankly say so.

In China, as in most other countries, by far the most important food article consists of the cereals. In the following table will be given the production of rice for the five years 1914 to 1918, during which period comparatively more complete reports were secured from the provinces by the central government.

| Year | Production, 1,000 "tan"[3] |
|---|---|
| 1914 | 2,133,483 |
| 1915 | 2,091,956 |
| 1916 | 538,853[4] |
| 1917 | 526,641[4] |
| 1918 | 302,297[4] |

The first two figures are supposed to be complete, but the last three, while generally cited as representing the total production of rice in China by those who are interested in Chinese agriculture, including the United States Bureau of Agricultural Economics,[5] are short of the amount of six or seven provinces which did not report to the Peking government. Assuming the average rice production of China in a normal year to be equal to the average of the amounts of 1914 and 1915, or 2,124,719,000 tan, we can form an idea of the approximate number of people who may be fed on rice. We will assume that an average person requires about three tan of cleaned rice to carry him through one year, and that two tan of rough rice or paddy are needed for making each "tan" of cleaned rice, and that the rice as reported by the government means rough rice throughout. We will assume, further, that it takes

[1] Customs Office.

[2] Ministry of Interior.

[3] 1 tan = 3.94 bushels.

[4] Incomplete total.

[5] "Foreign Crops and Markets," U. S. D. A. Vol. 6, No. 22.

roughly 10,000,000 "tan" of rough rice as the necessary seeds to start the next crop of 492,680,000 "mou,"[6] which is the average of the acreages of 1914 and 1915. Then rice alone will be sufficient to take care of about 352 millions of people.

The area and production of wheat are given by the Ministry of Agriculture and Commerce as follows:

| Year | Area, 1,000 "mou" | Production, 1,000 "tan" |
|---|---|---|
| 1914 | 277,298 | 265,853 |
| 1915 | 266,299 | 247,106 |
| 1916 | 404,920[7] | 360,112[7] |
| 1917[7] | 366,795 | 216,250 |
| 1918[7] | 571,799 | 356,748 |

The totals for the last three years do not contain the amount of all the provinces. But oddly enough, both the area and production are considerably larger than that of the preceding years. The production may vary widely from year to year, but it can hardly be believed that the area under wheat in the provinces which reported increased so fast as more than to cover the loss of the area caused by the withdrawal of several provinces which produce considerable quantities of this crop. It may be supposed, however, that in the first few censuses the government did not discover all the wheat area of all the provinces, and that in later years the officials were better able to require the provinces reporting to report more completely. But for our purpose it seems wise to take the average production of 1914 and 1915, which is 256,479,000 tan. After the necessary amount is deducted from the total for seeds there remains about 236,479,000 tan of wheat for the annual consumption as food. On the basis of three tan of wheat to each person a year, which is a little higher than the average per capita consumption of the Occidental people—an assumption justified by the fact that the people in the West eat considerably larger amounts of other food besides wheat, the above quantity of wheat will be enough for approximately 78,826,000 persons as a principal food article.

Other important cereals are millet, about 335 million tan a year, and kaoliang, over 100 million tan per annum. Both of these grains are the principal food items of the people in Northern China. Besides these cereals China also produces large quantities of other crops which are not used primarily for human consumption as a staple food, such as corn, oats, barley, beans, peanuts, potatoes, etc. Some incomplete statistics are given in the following table:

| Crops | Units of measure | 1917 | Production (000 omitted) 1918 |
|---|---|---|---|
| Corn | bushel | 97,230 | 171,450 |
| Barley, oats | " | 231,000 | 223,950 |
| Beans | " | 441,426 | 527,787 |
| Peanuts | " | 81,447 | 99,822 |
| Potatoes | ton | 2,238 | 4,384 |

It appears that China has, besides plenty of cereals for human food, enough grain for feeds to produce enormous quantities of meat. Practically all her people can live on wheat and rice alone if both the statistics and the assumption for the per capita requirement of food are accepted.

China is known as a country largely of vegetarians. There is no large-scale animal husbandry in China as in the new countries. Neither are there many farms solely or even primarily devoted to the rearing of animals. Cattle, the most important farm animal in the west, is kept in China primarily to furnish power for the farm rather than for the purpose of producing meat or milk. Many or most of the Chinese people do not eat cattle meat, largely because of superstition perhaps based on a real mercy to the poor, hard-working beast. Sometimes

[6] 1 "Mou" = 0.15 acre.

[7] Incomplete total.

the government officials even forbid, by heavy fines and bodily punishments, the slaughtering of cattle. Cow milk is very rare throughout the country. So there is no meat or dairy type of cattle in China. On the other hand, swine are raised almost everywhere, on the farms and even in the villages and towns. Poultry are universally kept by farmers and even by urban people. In South China where rice fields are common and water is abundant it is the rule for farmers to keep ducks. The sheep is a common animal in the north and goats in the south. In the mountainous regions herds of hundreds of sheep or goats are not infrequently met. With this general impression in mind we may go on to the government statistics of farm animals.

NUMBER OF FARM ANIMALS, EGGS AND NUMBER OF ANIMALS SLAUGHTERED IN CHINA

| | Number in thousands | |
|---|---|---|
| A. Farm Animals: | 1914 | 1915 |
| Horses | 4,934 | 4,744 |
| Cattle | 21,997 | 22,886 |
| Asses | 4,394 | 5,140 |
| Sheep and goats | 22,186 | 23,905 |
| Swine | 76,819 | 60,246 |
| | 1917[a] | 1918[a] |
| Poultry | 278,706 | 149,649 |
| Ducks | 65,137 | 52,249 |
| Geese | 10,411 | 5,795 |
| B. Eggs: | | |
| Hen | 5,144,359 | 4,489,703 |
| Duck | 1,842,802 | 1,035,194 |
| Goose | 246,161 | 133,268 |
| C. Animals slaughtered: | 1917[a] | 1918[a] |
| Cattle | 692 | 441 |
| Sheep and goats | 3,644 | 3,269 |
| Swine | 14,661 | 12,766 |

The number of farms is given by the Ministry of Agriculture and Commerce as 59,402,315 for 1914, and 46,776,256 for 1915. The ratio of farm animals to the number of farms seems to agree with our general impression. But it can hardly be believed that the figures for poultry and eggs are obtained by taking a real census of them, as such an undertaking would be impossible under the present condition in China. The number of animals slaughtered is probably more nearly accurate because the butchery of animals is reported and taxed.

We may now attempt to find out the per capita consumption of meat in China. Unfortunately the statistics of meat produced are not complete. The report for 1917 was incomplete by four provinces, the amount of meat for the rest of the country being about 1,549 million catties or about 2,014 million lbs.; that for 1918 did not include six provinces and the amount of meat for the rest of the country was 1,096 million catties or about 1,424 million lbs. The population for the provinces that reported in 1917 and for those reporting in 1918 was, respectively, 344 and 279 millions (according to 1919 post-office estimates). Therefore the per capita consumption of beef, mutton and pork together was from five to six pounds, which is exceedingly low as compared with the Western standards. It must be remembered, however, that the total consumption of meat must be considerably more than the above figures would show because, in the first place, both the weight and number of animals slaughtered were probably underreported on account of the meat taxes, and in the second place, the meat from such sources as poultry, fish and game is not included in the total, and lastly, the provinces omitted in the report probably consume more meat per capita than the rest of the country taken together.

From the above discussion and the personal observation of the writer, it seems safe to say that China produces in normal years just about enough food to feed her people fairly well and that she has as much meat as is absolutely necessary for a normal living, although not

[a] Incomplete total.

plenty of it. In a bad year she is bound to have a really hard time. As the economic status of the people is quite unequal it is needless to say that even in years of abundance some of the poor are only barely fed, while the wealthy lived lavishly even in the worst seasons. And as the country is so large, and the means of transportation so primitive it is very reasonable to expect that local famines occur practically every year and that there are always people starving or struggling for the barest living. In more recent years with the gradual industrialization of China and the rising standard of living in some sections and among some people, the demand for rice and wheat has become greater and greater every year, while on the other hand the production of them has probably been decreasing. Consequently, foreign cereals, particularly rice, are being poured in more and more every year. The average annual value of foodstuffs imported to China in the five years 1913–1918 was more than one hundred million taels of silver. The imports of rice, wheat and flour for 1921 and 1922 are as follows:

| | 1921 | | 1922 | |
|---|---|---|---|---|
| | Quantity 1,000 piculs[9] | Value 1,000 taels | Quantity | Value |
| Rice and paddy | 10,629 | 41,221 | 19,156 | 79,875 |
| Wheat | 81 | 302 | 873 | 3,058 |
| Flour | 753 | 3,504 | 3,601 | 16,740 |

The amounts are indeed insignificant as compared with the food imports of the United Kingdom. But it must be borne in mind that China is supposed to be an agricultural nation and to supply food to the world. It is certainly surprising to find that she is importing both manufactured products and foodstuffs, and that her food imports constitute about 20 per cent. of the total imports of the country.

Sad as the present situation may appear, there is no need for a pessimistic view of the future if the human factor is to conquer and to make use of its environment. There is a Chinese proverb which describes the condition in China exceedingly well and which may be expressed in the following English words: "Crying for hunger with jewels in hands." China is hungry, but she is not poor, because she has "jewels" in her hands. As soon as her "jewels" are properly utilized she will have no worry for food. Anybody who has any knowledge of geography should know the unlimited natural resources of China. She has the most fertile soils and the most favorable climates that the Creator can give to the world. A glance at the map of China will show that only about one third of the land is settled and cultivated, the other two thirds being yet unexplored. Of course the richest parts of China exist very largely in the well-settled one third of the area, but Manchuria, "the land of opportunities," as the Japanese call it, is as rich as any region of the country. Even in Mongolia, Tibet and Sinkiang extensive fertile tracts of land are reported by individual explorers as well as by government officials. Although nobody knows the exact or even approximate reclaimable area in such vast and untouched territories, the government has secured some figures upon which we may make some estimates. A recent report of the Ministry of Agriculture and Commerce gives the uncultivated cultivable land area as follows: in the interior 18 provinces, 125,065,000 mou; in the eastern three provinces (Manchuria), 788,162,000 mou; in Sinkiang (Chinese Turkestan), 7,594,000 mou; in the three special districts—Jehol, Sueiyuang and Tsahar,

[9] 1 picul is about 133 lbs. 1 tael is about 581 grains.

4,425,000 mou; or a total, not including Mongolia and Tibet, of 1,125,246,000 mou. By no means does this figure include all the reclaimable areas in those regions; at best it contains only those that have been discovered and recorded by the government. The best illustration for this inference is given by the province of Sinkiang, which has a total area of over 550,000 square miles or about 2,310 million mou, but which has a reported reclaimable area of only 4 million mou.

The reclaimable land in Mongolia is not reported by the Ministry of Agriculture and Commerce; not even the total area is accurately known. However, just about a year ago the ministry sent out a few men to Mongolia to investigate the conditions of reclamation over that region, and the report of the investigation appeared in a recent issue of the journal of the ministry. We found that these men, after about a month's expedition, probably on horseback in that vast territory, made an estimate—a wild and pure guess—of the reclaimable land area at the large round number of "about one million mou." These people also calculated that Mongolia can support 160,000,000 persons with the average standard of living prevailing in China. Their estimate not only is based on an unreliable assumption of the proportion of cultivable land but also involves an erroneous element in the calculation of the total area. A similar guess was made by the Chinese Bureau of Economic Information which stated in the *Chinese Economic Monthly* (October, 1923, p. 10) that "presuming that half of this area (outer Mongolia) is suitable for agriculture, we have 500,000 square miles or 32,000,000 (really 320,000,000) acres or 192,000,000 (really 1,920,000,000, or still more accurately 2,107,500,000) mou of arable land . . ." Such guesses may hit the actual fact, but we can never trust them because they have absolutely no scientific background.

The writer would put himself in the same situation that he has been criticizing if he were to make guesses, whether more conservative or less so. It is not only futile but misleading for anybody to attempt an estimate of the cultivable area in Mongolia or Tibet, even though he use million or billion as the unit, because nobody can claim that he has any genuine idea of the proportion of land that can be turned to agricultural uses. It means a lack of the sense of responsibility to make guesses purely from imagination. The writer, therefore, instead of making any estimate himself, will merely try to present the situation to the reader, using comparatively more reliable data so far as obtainable and making a few necessary suggestions. He will approach the problem from a different end—the amount of cultivated land—concerning which figures are relatively more trustworthy.

The more complete statistics of cultivated land (field and garden) were those secured in the years 1914 and 1915. For 1914 the total given, excluding Outer Mongolia, Tibet, Kweichow province and the special district of Sueiyuang, was 1,578 million mou; for 1915 the total excluded Outer Mongolia, Tibet, Yunnan province, and Sueiyuang, and was 1,442 million mou. The total cultivated area in Yunnan was given in one year as 11,497,000 mou; that of Kweichow, 1,471,000 mou; that of Sueiyuang, 5,208,000 mou. The area under cultivation in Mongolia was given as 300,000 mou by the Chinese Bureau of Economic Information.[10] As to how much land is cultivated in Tibet nobody dares to say. However, it is believed that the amount must be insignificantly small. It seems

[10] *Chinese Economic Monthly*, October, 1923, p. 10.

safe to say, in view of these facts, that the land area cultivated in all China must not be very far from 1,600 million mou.

Now the total area of all China is estimated at about 4,277,000 square miles, which is roughly equal to 18 billion mou. It means, then, that only about 9 per cent. of the total area of all China is cultivated land. If we disregard the territories of Mongolia, Tibet and Sinkiang and consider only the 18 provinces and Manchuria we would have a much larger proportion of cultivated area, or about 19 per cent. of the total surface. In order to know better the significance of these proportions the writer will compare them with similar figures of a number of other countries in the following:

| Country | Year | Percentage of cultivated land of total area |
|---|---|---|
| China, all | 1914–15 | 9 |
| " 18 provinces and Manchuria only | " | 19 |
| United States | 1910 | 15 |
| Canada | 1901 | 0.8 |
| Argentina | 1909–10 | 6 |
| Belgium | 1895 | 49 |
| Denmark | 1907 | 66 |
| Italy | 1911 | 48 |
| Britain | 1911 | 26 |
| British India | 1910–11 | 43 |

These figures do not seem to show that China is such an old country. However, it must be pointed out that the cultivated area includes fallows and artificial grasslands and that China has probably a smaller proportion of such lands than the western countries. But this difference will not affect the results very materially. Is China, then, a naturally poor land that can not even ultimately be extensively cultivated? Our impression is that it is far from being such. Our observation leads us to believe that it is probably not far more barren than either America or Europe. We are forced to believe that China is still a new country agriculturally which offers immense opportunities for agricultural expansion. This is about as far as the writer can safely go. He will let the reader form his own opinion with regard to the exact or probable limit to which agriculture may be extended in China. To tell him how many acres or mou can be put under rice, how many under wheat or millet or beans or how many can be used as vegetable gardens or dooryards would merely lead him to pure fancy.

Yet the writer does not feel that he is running a very dangerous risk in saying that the food supply of China can easily be doubled by opening up the virgin soils and by introducing scientific knowledge and practice to Chinese agriculture. Rice may be grown in some of the new regions, since its growing has already made remarkable success in Manchuria. Wheat, millet, kaoliang and other kinds of cereals will find the best type of soil and the most favorable climate in most parts of those territories. There also exist some of the world's best pastures and ranches. With the introduction of productive farm animals into those sections we may look forward to the day when packing plants such as are now found in Chicago will be established somewhere north of Peking, and when Chinese butter and cheese will be also produced in such plants.

But, although any addition of the amount of food equal to that required for four hundred million people to the world's stock is a very material gain, we must not suppose that China will have very large quantities of surplus staple food for the rest of the world. As the standard of living in China is rather low, and as reclamation must necessarily be a slow process and can only be pushed forth by the pressure of population and dear food, the increased output of food will be used largely for rais-

ing the standard of life of her own people and for feeding her own growing population. Her agricultural exports, while they may increase, will be largely confined to certain special products such as beans, vegetable oils, etc., unless the government can adopt very effective measures to promote agriculture and to reclaim the new lands. However, even if China will not export any foodstuffs at all, she will have fulfilled her duty, provided she can feed her own sons well, since she will then be supporting one fourth of the people of the world with only one thirteenth of the land surface.

China's food imports may continue to increase, but China will be able to pay for them, because she is one of the greatest nations on earth to-day whose natural resources other than the surface soil have not been touched. She is rich in minerals and coal and has plenty of water power and human energy. When the rest of the world has been exhausted in everything, it will be the time when China will turn her "jewels" into use. Then if she does not care to produce as much food as she will need and if other parts of the world can produce a surplus, China will buy food, paying with her minerals and manufactured products. So, although China is not very well fed at the present time, she has no more need to grieve for her future food supply than any of the richest countries in the world.

# AN ENGINEER'S VIEWPOINT

By Professor SUMNER BOYER ELY
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Some twenty or twenty-five years ago we were headed straight for the millennium. A strong optimism seemed to pervade all thought. After centuries and centuries of groping man had come at last to possess sufficient scientific knowledge to utilize nature's forces for his own benefit, and from this starting point civilization would go on and up in one unbroken line of progress. Every new discovery, every new invention was to help the human race along toward a condition where men would live in peace and harmony and where they could enjoy the kindly fruits of the earth with only as much labor as was good for them. What was to happen after this delightful state was reached was not very clear; presumably progress would then cease and we would live happily ever afterwards.

To-day a decidedly pessimistic note has come into man's thinking. To realize this we need only observe the titles of such books as: "The Decline of Western Civilization," "The Revolutions of Civilization," "Mankind at the Crossroads," etc. We have always believed this to be a changing world, but it is only within the last few years that we seem to have applied the facts of history to ourselves and to think that our civilization may be going through a cycle. Our civilization, which we had supposed so stable and believed nothing could overthrow, is now thought by many to exhibit tendencies and changes that will ultimately lead to its collapse. History seems to show that a civilization, like a man, goes through a period of growth, decay and death, and that new civilizations rise out of the ashes of the old. Some of the culture and learning of these old civilizations have been lost; much has been preserved in one way or other.

It is difficult to say what brought about this change in thought. One of the factors appears to be our more complete knowledge of the dates and history of ancient Egyptian and other archeological remains. Furthermore, no one can look at the wonderful sculptures and remains of ancient Greece, and then at the crude work and drawings that appeared during the early middle ages, and then again at the sculptures, cathedrals and pictures that were produced in the fourteenth and following centuries, and not believe that a cycle of some sort—a wave in civilization—had taken place; at least in the field of art. And now, in the last twenty-five years our records have become so complete that Flinders Petrie has been able to trace back some ten thousand years and distinguish eight such rises and falls. These different civilizations he has plotted in a curve, showing the high and low points in a series of waves, one succeeding the other in quite regular order. Some of the wave peaks are higher than others, for art in some of the older civilizations was better than in some of the newer ones. It would naturally be supposed, however, if we could go back far enough into the past, we would find that there had been a gradual increase in the *average* wave height.

History also shows that the way in which civilizations grow and develop is

much the same in each case. Art appears to reach a high point before learning, wealth or prosperity develop. Our own civilization, which started, perhaps, three or four centuries after the birth of Christ, produced its great cathedral architecture about the thirteenth century, while it was one hundred and fifty or two hundred years later before Michelangelo, Raphael and other great artists appeared; and still another hundred and fifty or two hundred years before literature culminated in Shakespeare; and then our scientific knowledge began to develop, while the accumulation of wealth and mechanical invention came last.

This same order of development is shown in all the older civilizations. For example: the Greek and Roman, which was all one civilization, started in Greece, where architecture, art and literature reached their high point. This culture was transmitted, without a break, directly to Rome; after which we find a spread of learning and then a great accumulation of wealth and power.

It is perhaps a little disturbing to think that if history is to repeat itself, it would seem that our present civilization has already produced its great artists and that there will be no more really great ones. Certainly some of the futurists and ultra-moderns of to-day give us reason to stop and ponder over this.

Civilizations appear to disintegrate from an internal wearing out, rather than from any outside cause. A people by the accumulation of wealth and comforts become soft and indolent, and are then either overrun by inferior races or simply degenerate into an inferior race themselves. As to the cause of this decline, there are many theories. The biologist tries to explain it by saying that as economic pressure becomes more and more severe, the families of the better classes become smaller and smaller until finally only a lower grade of intelligence is left.

No entirely satisfactory explanation of the fall of civilizations has yet been advanced and perhaps this of the biologist is the best we have at the moment. The basis of this theory is, of course, heredity; and means that a civilization might endure, if there were a radical change in man's character. Eugenics might do this; or possibly some chemical or physical method of embryonic control may be discovered later that will allow man to produce Nietzsche's overman, Bernard Shaw's superman or any other kind of man desired. Such knowledge, however, might be equivalent to giving mankind a stick of dynamite with which to exterminate himself. This of course is mere speculation and at best is so far in the future that it will be better to consider the question of the fall of civilization from a much more tangible and practical standpoint.

In what has been said the term "civilization" has not been defined; and probably a perfectly satisfactory definition could not be given; but every one will generally understand what is meant. However, so far as our purpose is concerned, definitions are unimportant; and further, it is unimportant whether the detail of development suggested above be accepted or not. The whole point simply is that we must all agree that many civilizations have existed in the past and that culture does not follow a continuously progressive evolution.

Now the question is: "Will our civilization go the way of the others or does it possess any new quality that might make it endure? Is there anything in our civilization which all the others lacked? Yes, there certainly is."

In the past, certain events must have affected mankind profoundly. When man discovered how to kindle a fire, it

must have opened new possibilities in his whole method of living. It allowed him to live in cold countries and to greatly enlarge his diet. Another such event was the domestication of certain animals. These things are prehistoric, but a similar happening has taken place almost under our own eyes and yet most people do not appreciate its full significance.

It is a very strange thing that in all the ages that man has existed on this planet, it is only about one hundred and fifty years ago that he discovered how to machine a flat surface and a cylindrical one. In other words, machine tools had their birth. The ancient world possessed a few crude grinding millstones driven by a rough kind of water wheel, but no machines actuating cutting tools. This may have been due possibly to metallurgical inferiority; but whatever the cause was, it remained for the later part of the eighteenth century to see the development of machine-driven tools.

The possession of two master tools, the lathe and the planer, has made it possible to build upon these as a basis the great superstructure of automatic machinery that we possess to-day. Great difficulty must have been encountered in making the first machines, for every surface, screw thread and spindle had first to be formed by hand. However, by building each new machine with the aid of the last, a reasonable degree of accuracy was finally obtained. In reading the history of the early steam engine, one is impressed with the difficulty Watt had in getting accurate machine work. In contrast to this, think of the great quantity of inexpensive, yet accurately made articles we have to-day—eyeglass lenses, to name only one example.

Before the days of machine tools, such a simple thing as drilling a hole correctly through a metal plate required a high degree of skill. The position of the hole must be carefully laid out, the drill must be so formed as to make a hole that will be truly round and not oval, and the drill must be guided through the plate at the proper angle; all of which required a practiced and highly skilled mechanic. How do we do this to-day? Simply make what is known as a machine jig, consisting of a steel plate the size of the plate to be drilled, in which has been fixed a steel bushing in the exact position for drilling the hole. This jig is given to a boy, who has only to clamp it over the plate to be drilled, put it in a machine and run the drill through the bushing. And now it is as hard for the boy to get it wrong as it was for the skilled man to get it right.

This is technically known as the transference of skill. The skill of the man has been transferred into the machine. In certain machines there is a transference of thought as well as skill. For example, to operate a pianola requires neither skill nor thought. In the shoe manufacturing industry to-day there is not a man who could make a pair of shoes. Pieces of leather are dropped into various machines and afterwards placed together and put into other machines until finally a finished shoe is produced. The shoemaker has become merely a machine tender.

The consequence of all this has been to change society from top to bottom. When textile machinery was first introduced by Jenney, Arkwright and others, it degraded labor, for the skilled workman who had learned this particular trade found himself replaced by unskilled labor and unable to earn his customary wages. Generally speaking, the introduction of machinery causes suffering, until labor adjusts itself to the new conditions and this often means a new generation of workmen before the adjustment is complete. It is true that we still need a few skilled workmen to make

the necessary jigs, dies and special tools, but they are very few, comparatively. However, while labor-saving machinery may at first degrade labor, it eventually produces goods in such abundance and so cheaply that all classes, including the laborer, share in the benefit. Never in history have wealth and comfort been so widespread and enjoyed by so many different classes of men.

A workman used to own his tools, but to-day these have become so elaborate and expensive that great corporations have taken them over and this has changed the old-time relation of employer and employee. The personal contact is gone, men are treated in a different way; organization, systematization, standardization are everywhere. Material advancement has come so fast that we have not had time to adjust ourselves to the new conditions, and this is undoubtedly the real cause of our labor difficulties. Just as the engineer brought about this industrial age, there is now some reason to believe he may bring the solution for its attendant troubles. It is a very significant fact that each year there are more and more technically trained graduates going into managerial positions. In other words, scientific knowledge and background are beginning to be applied to human engineering. In the last analysis the only real solution is education; education of both laborer and employer.

It may be argued that mankind was happier before this industrial age, with its railroads, its great steamships, telegraphs, telephones and the rest and that the tending of machines makes a workman into a mere automaton, deadening his faculties and killing his ambition and inspiration. There are, of course, two sides to this question; but whether it be true or not and whether we like it or not, the handwriting on the wall says that industrialism has come to stay and to increase. The signs read this way. The mechanical revolution not only made mass production possible, but it allowed science to advance by leaps and bounds. The high precision machine-made instruments have opened many closed doors of knowledge. Think of the accurately ground lens, the ruling engine and even surgical instruments.

The modern engineer, then, is the one thing in our civilization which no other civilization ever possessed. We differ from the past, in the wide spread of knowledge, the binding together of civilized peoples by railroads, telephones and telegraphs, the greater wealth in the world, the more uniform distribution of it, the much better condition of the working classes and the other things that came with the industrial revolution.

Is it possible that these new conditions can make our civilization endure? The mere fact that we have more material comforts does not mean that we are better or happier than men of past civilizations. The race does not reach happiness by mechanical or industrial progress. Man does not live by bread alone. He must progress intellectually and spiritually as well. When man ceases to strive he goes backward; and if security and plenty mean mental stagnation, then surely industrialism will only push him faster to the end. Yet there are certain influences acting to-day that must have a tendency to prolong at least the coming of this end.

Civilization can fall in only two ways. Either civilized man must deteriorate and change into uncivilized man or else he must be overrun and his culture stamped out. In the past, generally both of these have acted together; man first deteriorating and then some strong, hardy race, often from the north, coming down and conquering him. Sometimes the conquerors intermarried with the conquered and from this new infu-

sion of blood another civilization has in time started to rise.

The tendency of our age, due to railways, telegraphs and modern means of communication, is to spread civilization into the uncivilized portions of the globe, and to make the culture of the whole world more homogeneous. With culture so widespread a general deterioration of all civilized peoples at the same time is much less likely than in the more circumscribed communities of ancient times. The fact that cultured peoples are so scattered makes it difficult, too, to see how the oriental, for instance, could overrun and stamp out all western civilization. He might overrun part of the world, but western civilization covers a very large area. Then, too, the oriental may become westernized enough to prevent this. At any rate, we may conclude that modern conditions have in them a quality which will, at least, tend to prolong our present civilization and put further off that evil day when a general or partial deterioration may wreck or even destroy our culture.

There is one aspect of this question that should not be overlooked. In order that our civilization may continue we must have metals with which to build machines and coal to furnish power.

Metals have been produced and the arts of forging and tempering known since ancient times. An iron tool found in the pyramid of Kephron probably dates from 3500 B.C. and Homer compares the hissing of the stake thrown by Ulysses to that of the steel which the smith quenches in water. The ancient world was able to extract wrought iron only, and it was not until the fourteenth century A.D. that large furnaces and stronger air blasts made it possible to cast iron; somewhat as bronze had been cast long before. The small amount of iron ore that had been used before the advent of the modern blast furnace had made no impression whatever on the immense reserves contained in the earth; but now that modern metallurgy is demanding such enormous quantities of ore, our mineral resources are being used up at an alarming rate.

Coal, too, as well as iron ore, is necessary for our age. The industrial world of to-day is able to utilize but two sources of energy, *viz.*, water power and coal. Only about one fifth of the potential water power of the United States is at present developed; but even if it were all developed, it would not have carried the industrial load of the country during the year 1922 (for which the figures are available). Furthermore, estimates show that the industrial load of the United States is growing very rapidly. For instance, if the load curves of Pennsylvania, our greatest industrial state, are projected into the future, the indications are that the power demand will have doubled by the year 1950. This means that as the industrial world becomes larger and larger we must depend upon coal almost entirely.

The coal reserves of the world are fairly well known, and from some late estimates it would seem that a few hundred years will see the exhaustion of all our best coal. This means that industrial prosperity would reach its zenith at that time and from then on there would be a gradual decline in industry. As some one has said, it is a fortunate thing for us that the industrial age did not begin in the time of Tutankhamen or today we would be fighting among ourselves for the last few remaining heat units.

As to other fuels, our natural gas and wood are pretty well gone already and our oil is following very fast. Such sources of energy as wind, wave, the sun's radiation, the internal heat of the earth (if it exists), etc., can all be put in the same class. They have all been

tried and all proved unsuccessful. The chief reason is that the power is too diffuse. For example, it would require an enormous platform riding on the waves to generate even a few horsepower. Great numbers of parabolic mirrors have been placed around a boiler to gather the sun's rays, but have been unable to raise steam, much if any, above atmospheric pressure. It is true that some power can be obtained from these sources, but to develop by their means the tremendous amount of power demanded by the industrial world is entirely out of the question. Whether science will later tell us how to utilize the energy that we believe to be in the atom is doubtful to say the least.

The application of scientific principles has been so rapid and we have seen such spectacular changes taking place in industrial life that we have come to believe this development will continue and that sooner or later some one will stumble on some great source of energy other than coal. We are like Micawber, waiting for something to turn up. A much more logical attitude would be one of trying to conserve our resources. Future generations may regard the way this generation wasted natural resources as little short of a crime. Considerations of this kind, however, generally conclude with the question, "What has posterity ever done for us?"

The exhaustion of our natural resources has a very important bearing on the duration of our industrial civilization and may limit it and even bring it to an end.

# THE SCIENTIFIC MEN OF THE WORLD

By J. McKEEN CATTELL

THERE has for a long time been planned a study of the scientific men of the world on the lines of the statistical work on American men of science. International directories in the several sciences were taken up, those in psychology and zoology having been partly prepared, the latter in cooperation with Professor T. D. A. Cockerell. In connection with the third edition of the Biographical Directory of American Men of Science it was proposed to select by objective methods the thousand leading scientific men of the world. With such a list it would be possible to determine among other things the value of the contributions of each country to each science, both in quantity of work accomplished and in fundamental advances.

In order to obtain preliminary data I wrote in June, 1914, to the scientific academies of different countries asking for their membership lists. These were mailed from most of the German and other academies after war had begun. It was obviously impossible to continue the work at that time; it was indeed necessary to postpone the preparation of the third edition of American Men of Science. We have scarcely yet reached a situation where international cooperation and unprejudiced judgments are feasible; but the methods used enable us to measure validity of judgments and prejudice, so that the study might at the present time be of special interest from that point of view. We could, for example, measure the normal distortion of judgment through nationality, its excessive manifestation during war and its subsequent waning.

In connection with the study begun some years ago I counted up the scientific men of different countries in "Who's Who in Science," edited by H. H. Stephenson and published in England by Churchill. There has been no edition of the book since 1914, and the figures just before the war are no longer valid, but they have sufficient interest to warrant their publication, more especially in view of the recent widely quoted remark by Secretary Hoover to the effect that the United States is behind most European countries in its contributions to pure science and the statement of the National Research Endowment of the National Academy of Sciences to the effect that "the United States, which already occupies a leading position in industrial researches, should rank with the most enlightened nations in the advancement of pure science."

The scientific men whose biographies are included in "Who's Who in Science" and whose numbers are given in the table were probably selected somewhat at random, those of Great Britain and its colonial empire being the most completely represented and the United States coming next. Perhaps 800 from Great Britain and 1,200 from the United States would be a fairer basis for comparison with other countries than the 1,729 given from the former and the 1,845 from the latter. In that case Germany would be in the lead. The numbers from the non-English speaking nations may be regarded as comparable, though they doubtless vary with the sources of information.

If we take the figures as they stand, the United States, Great Britain and Germany were in 1914 far in advance of other nations in the numbers of their scientific men. France had 504, as com-

THE DISTRIBUTION OF SCIENTIFIC MEN ACCORDING TO "WHO'S WHO IN SCIENCE," 1914

| | Medicine Surgery | Chemistry | Engineering | Zoology | Mathematics | Geology Mineralogy | Physics | Botany | Physiology Pharmacology | Astronomy Meteorology | Pathology | Anatomy | Agriculture Forestry | Psychology | Geography | Anthropology | Total | Per million ca. 1860 | Per million ca. 1920 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| United States | 206 | 245 | 201 | 184 | 126 | 135 | 131 | 114 | 86 | 75 | 69 | 54 | 76 | 95 | 18 | 30 | **1845** | *58.7* | *17.4* |
| Great Britain | 252 | 295 | 349 | 118 | 86 | 90 | 104 | 78 | 53 | 64 | 51 | 37 | 59 | 30 | 42 | 21 | **1729** | *59.4* | *36.6* |
| Germany | 221 | 144 | 128 | 90 | 115 | 93 | 104 | 75 | 59 | 63 | 39 | 53 | 48 | 37 | 44 | 21 | **1334** | *35.0* | *22.3* |
| France | 109 | 52 | 23 | 32 | 32 | 27 | 39 | 16 | 33 | 16 | 30 | 24 | 8 | 12 | 16 | 16 | **504** | *13.7* | *12.8* |
| Austria-Hungary | 67 | 56 | 42 | 27 | 39 | 31 | 40 | 21 | 24 | 22 | 22 | 31 | 7 | 14 | 18 | 6 | **467** | *13.5* | *8.8* |
| Asia | 40 | 39 | 47 | 16 | 9 | 9 | 14 | 21 | 16 | 14 | 6 | 8 | 21 | 3 | 6 | 0 | **269** | — | — |
| Italy | 37 | 17 | 8 | 13 | 29 | 18 | 18 | 10 | 16 | 14 | 21 | 11 | 1 | 12 | 16 | 5 | **246** | *9.8* | *6.3* |
| Switzerland | 38 | 26 | 13 | 16 | 19 | 12 | 9 | 11 | 15 | 5 | 13 | 9 | 6 | 10 | 9 | 4 | **215** | *86.0* | *55.1* |
| Norway | 34 | 15 | 21 | 18 | 8 | 14 | 9 | 11 | 8 | 7 | 3 | 3 | 8 | 6 | 3 | 2 | **170** | *106.2* | *65.4* |
| Holland | 18 | 14 | 3 | 39 | 9 | 8 | 12 | 10 | 13 | 7 | 9 | 6 | 0 | 6 | 4 | 1 | **159** | *48.2* | *23.4* |
| Canada | 16 | 18 | 19 | 9 | 7 | 29 | 13 | 5 | 7 | 6 | 6 | 3 | 7 | 2 | 1 | 5 | **153** | *45.0* | *17.4* |
| Australasia | 12 | 11 | 30 | 10 | 10 | 19 | 8 | 7 | 4 | 8 | 5 | 4 | 10 | 3 | 1 | 3 | **145** | *120.0* | *19.4* |
| Russia | 19 | 17 | 10 | 12 | 12 | 10 | 9 | 9 | 5 | 8 | 5 | 8 | 0 | 6 | 3 | 3 | **136** | *2.0* | *1.3* |
| Sweden | 20 | 17 | 6 | 10 | 8 | 9 | 5 | 11 | 6 | 8 | 2 | 9 | 0 | 4 | 7 | 2 | **124** | *32.6* | *21.0* |
| Denmark | 11 | 11 | 14 | 9 | 7 | 4 | 3 | 9 | 8 | 3 | 4 | 4 | 4 | 2 | 4 | 0 | **97** | *60.6* | *29.4* |
| Belgium | 20 | 9 | 7 | 8 | 6 | 3 | 3 | 5 | 7 | 2 | 10 | 4 | 0 | 2 | 3 | 1 | **90** | *19.1* | *12.0* |
| Africa | 11 | 4 | 15 | 11 | 6 | 8 | 2 | 8 | 1 | 10 | 2 | 1 | 8 | 0 | 1 | 0 | **88** | — | — |
| Spain | 6 | 7 | 1 | 4 | 4 | 4 | 5 | 1 | 2 | 5 | 7 | 6 | 0 | 2 | 1 | 3 | **58** | *3.7* | *2.7* |
| S. & C. America | 5 | 2 | 3 | 5 | 2 | 8 | 2 | 3 | 1 | 10 | 3 | 0 | 3 | 2 | 1 | 2 | **52** | — | — |
| Portugal | 6 | 2 | 1 | 3 | 7 | 4 | 4 | 3 | 3 | 1 | 4 | 4 | 0 | 2 | 2 | 1 | **47** | *13.0* | *7.8* |
| Bulgaria | 0 | 3 | 0 | 3 | 2 | 2 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | **14** | *7.0* | *2.8* |
| Roumania | 0 | 1 | 0 | 1 | 2 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | **8** | *2.9* | *.5* |
| Greece | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | **2** | *1.8* | *.4* |
| Servia | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | **2** | *2.0* | *.4* |
| Malta | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **1** | *7.1* | *4.4* |
| Total | **1158** | **1006** | **941** | **638** | **546** | **537** | **536** | **429** | **369** | **351** | **320** | **280** | **266** | **250** | **201** | **127** | **7955** | | |
| U. S. Per cent. | *.18* | *.24* | *.21* | *.29* | *.23* | *.25* | *.24* | *.27* | *.23* | *.21* | *.22* | *.19* | *.29* | *.38* | *.08* | *.24* | *.23* | | |

pared with 1,334 from Germany; the then Austria-Hungary with 467 was nearly equal to France; Italy had 246. There then follow Switzerland with 215, Norway with 170 and Holland with 159. Sweden has 124 and Denmark 97.

According to the figures in the table referring to the several sciences, the United States stands higher in the so-called pure sciences than in medicine and engineering. We indeed stand first in all the natural and exact sciences except chemistry (largely an applied science) and geography. It is naturally gratifying to the present writer that psychology is the science in which we are most decidedly in the lead. We have 95 of the world's leading psychologists as compared with 30 in Great Britain, 37 in Germany and 12 in France. Geography is the science in which we are most deficient, 18 geographers being attributed to the United States, as compared with 44 to Germany and 42 to Great Britain. After psychology we are strongest in zoology, botany, agriculture and geology. This is what I guessed in a preceding discussion[1] of the subject, but I then added astronomy to psychology, zoology, botany and geology as the subjects in which we were probably in the van. The sciences in which we make relatively the poorest showing in the table, apart from the applied sciences and geography, are anatomy and astronomy. The differences in the percentages for the different sciences are, however, not large and would probably fall within the probable errors of sampling if these could be determined.

The figures in the table relate to a period preceding 1914. They do not have great validity even for that time, and the years that have since elapsed

[1] "Scientific Research in the United States," *Science*, February 12, 1926.

have been significant for international changes. The edition of American Men of Science published in 1910 contains about 5,500 biographies of those who are supposed to have made contributions to science, the edition now in course of preparation will contain in the neighborhood of 15,000. The increase may to some extent be due to more complete representation, but in the main it measures the increase in the number of scientific workers. They have probably about doubled since the data were compiled for "Who's Who in Science." The increase has been much less elsewhere; indeed there may have been none in some nations, such as France and Italy. With the possible exception of Germany the United States is now far in advance of every other nation in the number of its scientific men and in the number of its contributions to science.

It does not follow that the number of great men of science and the significant contributions are proportional to the total number of workers and the total amount of publication, although this is perhaps the most probable situation if there is no information to the contrary. It seems that England and ancient Greece have produced more than their share of the greatest men and this was indeed found to be the case in my study of the eminent men in the world's history.[2] It may be that at the present time Holland with 12 physicists attributed to it is making more important contributions to that science than the United States with 131. In psychology, which is the only subject on which I can speak with adequate information, we appear to lead in importance as well as in quantity of work.

In the last two columns of the table are given the numbers of scientific men in proportion to the populations of the different countries. The first column gives the numbers per million in 1860, which was about the average time at which they were born; the second column gives the numbers in relation to the present populations. In France, with a nearly stationary population, the figures in the two columns are of course nearly the same. In the United States and the British Dominions, with rapidly increasing populations, the proportion is much smaller in relation to the existing population than to the birth rate. For a given stock and civilization, if scientific productivity were wholly due to the innate constitution of the individual, the numbers should be proportional to the population at the time of their birth; if wholly due to opportunity it should be proportional to the existing population. An adequate study might contribute toward the solution of this problem.

Taking either the one figure or the other in the table, it is obvious that while in total productivity we may surpass every other nation, this is far from being the case in proportion to our population. This situation is still less creditable to us when wealth and opportunities for higher education are taken into consideration. It should, however, be noted that the lower figures can be attributed in part to the large Negro and immigrant populations and to an unproductive South. Our scientific men appear now to be increasing about four times as rapidly as the population, and the figures in the table have for this and other reasons (including redistribution of populations after the war) only a limited application. When allowance is made for disturbing factors, the number of scientific men of standing in proportion to the present population appears to be nearly the same in the United States, Great Britain and Germany, about half as large in France and a quarter as large in Italy. Norway and Switzerland have

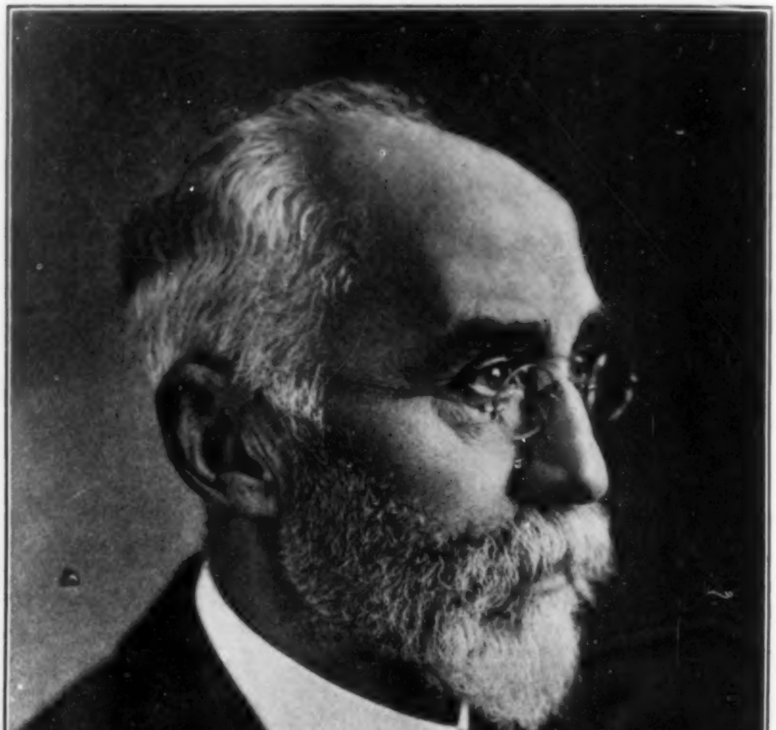
[2] "A Statistical Study of Eminent Men," *The Popular Science Monthly*, February, 1903.

by far the largest proportion, followed among the smaller nations by Denmark, Holland and Sweden. I should have expected Holland to stand first, and it may, for the figures collected from the book have inconsiderable validity.

The greater relative productivity of the smaller cultural nations in science—the same situation probably holding in literature and in art—is a matter of considerable interest. It goes back to the Greek democracies and to the Italian states of the renaissance. In this country we had a local development in Massachusetts and Connecticut, in which, according to my statistics, the birth rate per million population of scientific men more highly selected than those on the international list was 109 and 87, respectively. If these figures are increased to make up for the number of scientific men given in the table, they become, respectively, 201 and 160, a much larger birth rate of scientific men than that of any foreign nation. It is probable that a similar situation now holds in California and in parts of the central west.

We apparently need regional cultivation of special fields with a group and a community interest in the work. The situation is difficult for with the increasing complexity of science and in our existing competitive system there must be support of research through taxation or gifts. But control from Washington, whether by the national government, or by a group of men who administer philanthropic funds, may do more to suppress research than to forward it, the rarer flowers of genius being particularly apt to wither when frost and sunlight are artificially controlled.

We are so ignorant of the causes of scientific productivity that it is possible for Galton to attribute it almost wholly to heredity in superior lines of descent, for Odin to claim that genius is in things, not in men. Yet it is a subject of fundamental importance both from the point of view of constructive science and for the applications of science to human welfare. The field is nearly untilled and for that very reason may prove to be fertile.



*—From Nature*

PROFESSOR H. A. LORENTZ

THE DISTINGUISHED DUTCH MATHEMATICAL PHYSICIST, WHO IS VISITING THIS COUNTRY TO GIVE LECTURES AT THE CALIFORNIA INSTITUTE.

# THE PROGRESS OF SCIENCE

By Dr. Edwin E. Slosson

*Director of Science Service, Washington, D. C.*

## TROPICAL WEALTH

I have just received the reports of the British Association for the Advancement of Science and am much struck by the contrast between the parent association and the American Association for the Advancement of Science. In the British Association much more attention is given to the scientific aspects of the industrial and commercial development of the empire than is customary in the American Association.

At the recent Oxford meeting the presidential address of the Section on Geography was given by the Honorable W. Ormsby-Gore, Member of Parliament and Under-Secretary of State for the Colonies, who spoke on "The Economic Development of Tropical Africa and its Effect on the Native Population." He began by calling attention to the fact that "four million square miles of Africa lie within the British Empire. In fact there is more of the British Empire in Africa than in any other continent. British North America and Australasia are both smaller in area than the African possessions of the Crown. Approximately three quarters of this African area lie within the Tropics."

The advantages which Great Britain gets from her African dependencies is illustrated by a few of the figures that he gives. The domestic exports of Nigeria in 1921 were valued at $41,250,000, in 1925 they had risen to $85,000,000, more than double. In 1921 the Gold Coast products were valued at $30,000,000, in 1925 they were worth $52,500,000. These examples of expansion in West Africa are eclipsed by the rate of progress in East Africa. The domestic exports of Kenya and Uganda in 1921 were $11,250,000, in 1925 $39,100,000. What used to be German East Africa but is now rechristened Tanganyika Territory produced in 1921 products valued at $5,000,000, in 1925 these were $14,500,000. The two most sensational examples of the expansion have been cocoa in the Gold Coast and cotton in Uganda. The exportation of cocoa from the Gold Coast rose from 7,000 tons in 1905 to 78,000 tons in 1915 and 220,000 tons (nearly half the world's total supply) in 1925.

The peanut, which most Americans regard as merely a rival for popcorn as a mid-meal nibble, is becoming in Africa a source of oil for shortening, for soap making and for Diesel engines. The export of peanuts from Nigeria was nothing in 1910 and 120,000 tons last year. These figures will serve to intimate the rich revenues which Great Britain is gaining from the African territories that she possessed before the war and which she has acquired from Germany through the war.

The United States is handicapped in comparison with her commercial rivals by lack of tropical territory. England, France, Holland and Portugal are far more fortunate in this respect. England has about a hundred times as much territory as the United States in tropical or semi-tropical climes; France has over 34 times; Holland and Portugal have each more than seven times as much as the United States.

THE SCHOOL OF MEDICINE AND DENTISTRY OF THE UNIVERSITY OF ROCHESTER

THIS PHOTOGRAPH FROM THE AIR SHOWS THE BUILDINGS DEDICATED WITH SUITABLE CEREMONIES ON OCTOBER 25TH AND 26TH.

## DRIVING A HALF MILLION HORSES

I HOLD in my hand as I am writing the tooth of a horse. Yes, that is literally true, for I am so skilful on the typewriter that I can run it with two fingers of one hand with an occasional punch with the left thumb, and the tooth is not attached to the horse. In fact, the owner of the tooth has been dead for some 25,000 years. For this is a relic of one of the earliest horses made use of by man. It was picked up last summer at Solutre in France where tons of bones of a hundred thousand horses are piled up about a prehistoric camp of two acres area like tin cans about a frontier town. They are alike the débris of the kitchen. Yet before the Solutreans had deserted this site they had perhaps learned how to utilize the energy of the living horse, for an engraving has been found of the outline of a horse with some scratches on his head that look like a halter.

This then marks about the beginning of what we might call the Equine Epoch of human history, which is visibly drawing to an end in our generation. Look down a street of any of our large cities and you will rarely see a solitary horse struggling to hold his place in the throng of his mechanical rivals.

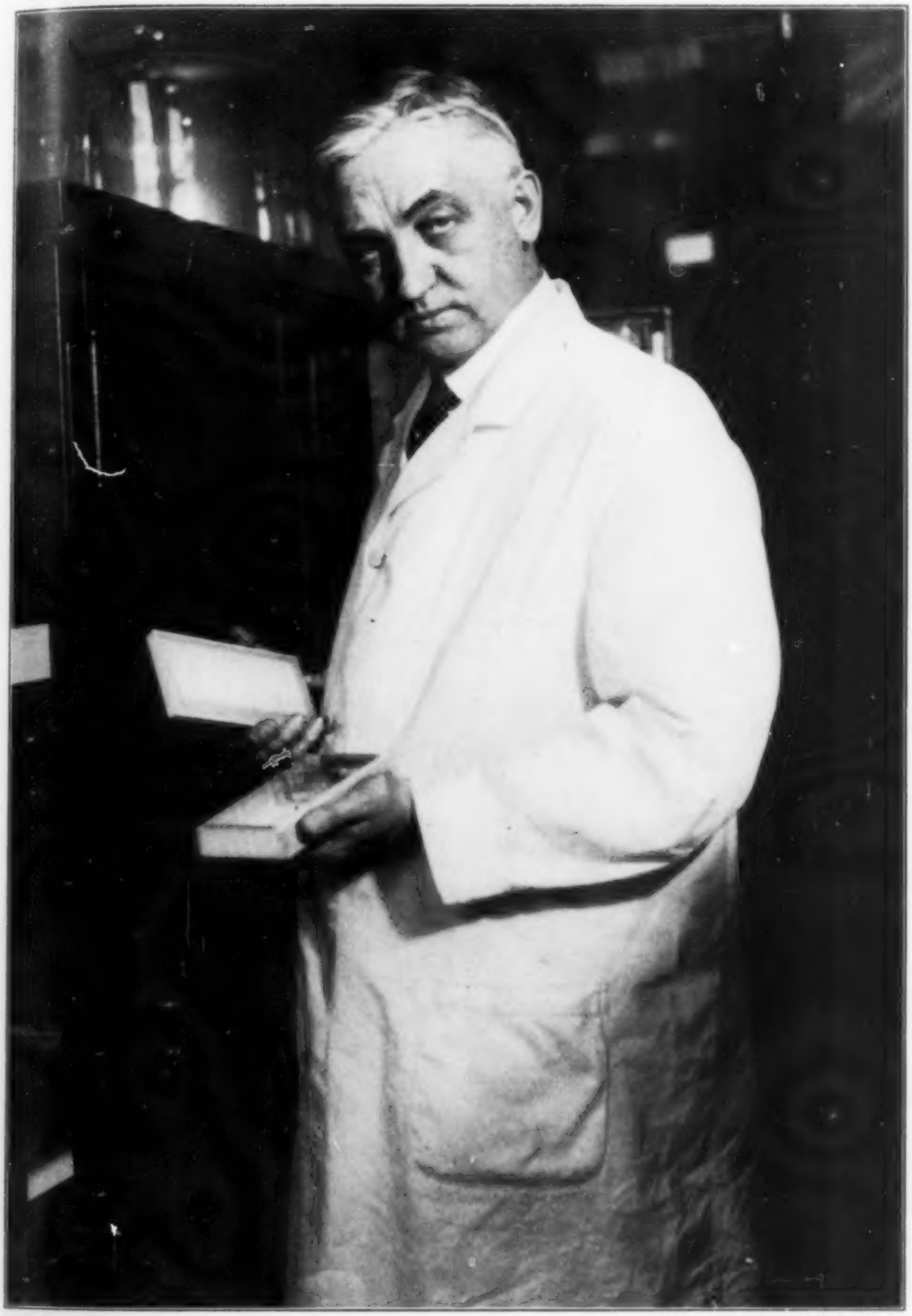
For the patient beasts of burden which primitive man trained to work for him, the horse, the ox, the ass, the elephant and the camel, are neither strong enough nor speedy enough to meet the needs of modern man. Nor are they tractable enough. "The horse is a vain thing for safety," said the Psalmist. That is because the horse has a will of its own. So has the mule. But machinery behaves more rationally than animals because it is the offspring of man's reason, created expressly to do his will. Being made after the manner of man's own mind, it is more completely under his control, provided he knows enough to manage what he has made.

To drive a team of six or eight horses requires a man of peculiar strength and skill. Yet the other day I saw a man driving a team of nearly 500,000 horsepower with the greatest of ease. It was in the switch room of the Niagara power house. In the middle of the clean and empty room was a desk at which sat two men. One was reading a paper so I don't count him. The other sat quietly and for the most part idly, though keeping a watchful eye on the dials, signals and switches that encircled him on the walls. Occasionally he touched a button or pulled a handle, jotted down a figure on a sheet of paper on the desk or took up the telephone. He looked more like a bank president than a "workingman." He must have to do a daily dozen to the tune of a radio in order to get enough exercise. Yet he had under his thumb the highest powered prime-movers in the world, three hydro-electric units capable of carrying a load of about 84,000 horsepower each. Only seven men are required to run the entire plant, but fourteen more are needed to show visitors around. These turbines and dynamos, with their few attendants, distribute light and power to an area of two million people. Such an example of individual control and democratic distribution would be impossible to accomplish with any number of horses—or elephants. It is an epitome of human progress, this passage from the hundred thousand horses that the Solutreans ate to maintain their muscular energy, on up to the five hundred thousand horsepower waterfall that this man employs to replace human energy.


—*Science Service Photograph*

EARTH'S OLDEST GRAVE

THIS MONUMENT WAS ERECTED BY DR. EUGENE DUBOIS TO INDICATE THE SPOT WHERE HE FOUND THE REMAINS OF PITHECANTHROPUS ERECTUS, SO-CALLED "APE-MAN," AT TRINIL, JAVA, 35 YEARS AGO. IT IS AT A LITTLE DISTANCE FROM THE EXACT SITE, TOWARD WHICH THE ARROW POINTS. THE RECENT FIND OF A NEW RELIC OF PITHECANTHROPUS WAS MADE NEAR THIS SAME SPOT.



—*Science Service Photograph*

THE YOUNGEST HUMAN EMBRYO

DR. G. L. STREETER, DIRECTOR OF THE DEPARTMENT OF EMBRYOLOGY OF THE CARNEGIE INSTITUTION OF WASHINGTON, HOLDING BOX OF MICROSCOPE SLIDES ON WHICH ARE PRESERVED SECTIONS OF THE MILLER OVUM, THE EARLIEST-STAGE HUMAN EMBRYO SO FAR DISCOVERED. IT IS KEPT AT THE JOHNS HOPKINS UNIVERSITY.

## SCIENCE IN DAILY LIFE

THE American Library Association has asked me to write something about the importance of the physical sciences for one of their forthcoming pamphlets on "Reading with a Purpose." This is what I said:

Ignorance of the laws of nature excuses no one. We have to live in accordance with them if we are to live at all, and the more we know of them the better we can live. The unprecedented expansion of civilization in the last two centuries, the immense increase in wealth and the general diffusion of the comforts and conveniences of life, must be credited chiefly to applied science, and especially to the physical sciences, since the biological, psychological and social sciences have not yet developed to a point where they exert so powerful an influence upon mankind.

It is interesting and important to learn about things far away and long ago, such for instance as the habits of the auks of the Arctic or life in Egypt in the time of the Pharaoh Tut-Ankh-Amen, but after all we can live, and even be happy, in complete ignorance of these things. But we can not carry on our work for a day without making some use of the laws of the physical sciences whether we are conscious of them or not.

Fortunately we are forced to learn a lot about them in our infancy, long before we go to school. It is pounded into our brains by hard knocks. We have to acquire a practical knowledge of the law of gravitation in childhood before we are able to walk, and we learn a good deal about chemistry by the experimental method of putting everything into our mouths and so testing it by taste and smell, which are the two senses that distinguish substances by their chemical constitution.

So every grown person, though he may never have been to school, gains through his daily life and occupation a considerable knowledge of the physical sciences. He gets, for instance, a certain familiarity with the physical principles of machinery and with the chemical properties of metals and foods. But the knowledge so accidentally acquired is fragmentary and often fallacious. The information that he has so picked up is not connected, and he can not apply it to new problems. Such a man knows more than he knows he knows, but he is not able to make full use of it because he has never connected his facts or generalized his ideas. In short, such a casual collection of fragmentary facts is not science, but merely the raw material for science. What such a man needs is to read some simple systematic work on the physical sciences, and he will then find that the practical points he has picked up will fall into their proper places in the general laws, and that these laws will extend his vision and throw new light on all that he sees and does ever after. To study physics and chemistry is like giving sight to a blind man. It opens to him a new world of undreamed-of beauty, meaning and possibilities.

But simply because these physical sciences are so fundamental and essential they are apt to be overlooked and neglected in the acquirement of culture. When tourists visit a Gothic cathedral many of them see nothing but the frescoes and gargoyles, and give no thought to the architectural principles of its structure, yet the esthetic effect of the edifice is due largely to the way the structural principles are revealed in its pillars, buttresses and arches. One who fails to get that misses, not only the meaning, but much of the beauty of the building. So, too, one who, for lack of acquaintance with the physical sciences, does not see the inner meaning of the acts and processes of daily life, not only is hampered in their control, but loses the enjoyment of their significance.

EXHIBIT OF THE SMITHSONIAN INSTITUTION AT THE SESQUICENTENNIAL EXPOSITION

DR. JAMES M. GIDLEY, OF THE U. S. NATIONAL MUSEUM, IS SHOWN WITH ONE OF THE EXHIBITS PREPARED BY HIM FOR PHILADELPHIA. THE SKELETONS ARE TWO PORTHEUS FISHES, ONE TWELVE FEET IN LENGTH WHICH IS SWALLOWING ANOTHER WHICH MEASURES SIX FEET. THE BONES WERE FOUND IN KANSAS, WHERE THE GIANTS FLOURISHED MILLIONS OF YEARS AGO.

## THE FLORIDA HURRICANE

*Science Service*

THREE severe tropical hurricanes in the region around the Caribbean Sea at the same time, one of which was the disastrous storm which swept Florida and the northern Gulf Coast, have made a new kind of weather record, according to Charles L. Mitchell, of the U. S. Weather Bureau.

Fortunately, only one of the three got to the mainland of the United States. One of the others kept to sea as it passed up the Atlantic Coast, and it was this one that prevented Captain René Fonck from taking off on his airplane flight to Paris immediately after he had repaired his leaking gas tank. The third member of the trio passed northwards over Cuba, and then disappeared with the proximity of the Miami hurricane.

But though millions of dollars' worth of damage was done in Florida, the storm was not a surprise to the Weather Bureau officials, for they had been observing its progress since the fourteenth of September. Warnings of a hurricane along the eastern coast of Florida were sent out on the evening of Friday, September 17, preceded by warnings of a severe storm the same morning.

The origin of the storm was off the west coast of Africa, near the Cape Verde Islands, a favorite breeding place of such hurricanes, and the Atlantic storm began in the same general region. The Miami storm began about September 18, the mass of whirling air that constitutes such a hurricane then passing westward across the Atlantic, and, when it hit Florida, traveling with a speed of about 125 miles a day.

Apparently the center of the storm passed right over Miami, for at the center of the whirl of air is a calm spot perhaps forty miles across, called the "eye of the storm." After the first severe blow at Miami, the storm apparently ceased, but as the rescuers were beginning their work it broke again with increased fury, but then the wind, instead of coming from the northeast, as it had at first, came from the southwest. While it was at its height, the wind velocity went up to about 125 miles an hour, while the barometric pressure dropped to 27.62 inches, the lowest ever recorded at a U. S. Weather Bureau station.

Hurricanes always originate, according to Dr. W. J. Humphreys, professor of meteorological physics at the Weather Bureau, in the doldrums, a region about ten to twenty degrees from the equator, which is characterized by relatively calm air. The Cape Verde Islands, where the Miami storm originated, are in this area; but hurricanes are not peculiar to the Atlantic Ocean, for the typhoons of the coast of China and the Philippines are similar, and they also occur in the Indian Ocean and, south of the equator, near New Zealand. However, those which occur south of the equator differ in an important respect from their northern counterparts, for while the air in the latter whirls in a counter-clockwise direction, the southern hurricanes whirl clockwise. This is an effect of the rotation of the earth. The exact cause of the whirls is unknown, but it is certainly not due merely to two winds in opposite directions happening to come close together, for such a whirl could be no greater than the relative motion of the two original winds. In a hurricane, wind velocities far in excess of any relative motion between opposing air currents are often observed. In addition to the whirling winds, there is an ascending current of air towards the center, which produces the torrential rains.